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THE WHITE PINE

THE WHITE PINE

A STUDY

WITH TABLES OF VOLUME AND YIELD

BY
GIFFORD PINCHOT
AND
HENRY S. GRAVES

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PREFACE

THE inquiry upon which this study of the White Pine is based was made possible through the public-spirited and generous coöperation of Mr. William E. Dodge, Mr. D. Willis James, and Mr. James W. Pinchot. The fund which they subscribed was placed in the hands of Mr. Henry S. Graves, by whom the notes and measurements summarized in the following pages were collected in the field.

During the summer and autumn of 1894 the work was prosecuted on the ground, and for two months of that time Mr. Graves was assisted by Mr. P. F. Nash, Jr., who gave his enthusiastic and helpful services entirely without cost to the fund. After the conclusion of the field work, the delicate and laborious task of calculation and tabulating the results was carried on by Mr. Graves, and by him brought to an end. He also prepared the silvicultural notes, based on his observations, which were used as the framework of the letter-press of this study; and the small tables in the text are wholly his own.

The general plan of the work and the detailed instructions according to which the notes and measurements were taken originated with the undersigned. He is also responsible for such criticism as his experience suggested, and for the ultimate form into which the conclusions have been cast. He wishes to express, both for Mr. Graves, now prosecuting his forest studies abroad, and for himself, a deep sense of obligation to the gentlemen whose wise and kindly action has resulted in this first systematic description of the growth of a North American tree.

Sincere thanks are also due to Dr. W. Schlich for the table taken from his Manual of Forestry, and to Prof. C. S. Sargent, who has been kind enough to look over the proof of Chapter III., and to bring such of the Latin names as have recently been changed into conformity with the latest progress of botanical nomenclature. Prof. Sargent is not responsible, however, for the omission of capital letters in certain of the specific names.

Mr. Morris K. Jesup has been good enough to permit the use of a drawing from which the design on the cover has been adapted, and Mr. Romeyn B. Hough has kindly furnished the photograph of a first-growth Adirondack Pine reproduced in the frontispiece.

The facts and conclusions here presented, based as they are on a short period of observation and a comparatively restricted number of measurements, must of necessity be susceptible of enlargement, and perhaps of correction also, as the result of more extended investigations. Meanwhile, observations and measurements which may be forwarded to the address below will be exceedingly welcome, whether they tend to confirm these conclusions or to disprove them. Any material bearing upon the contents of this study, or upon any phase of the life, growth, or utilization of the White Pine, will be very gladly received.

The motive which gave rise to this attempt, in the minds of all those who have shared in the work, was the desire to assist in making clear the real nature of forestry, in exciting an interest in the subjects with which it deals, in stimulating others to similar research, and, above all, in facilitating and hastening the general introduction of right methods of forest management, by which alone our forests can be saved.

GIFFORD PINCHOT.

GREY TOWERS, MILFORD, PA.,
March 7, 1896.

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THE WHITE PINE

INTRODUCTION

THE silvicultural notes contained in this pamphlet are intended both as a contribution to the natural history of the White Pine and its neighbors, and as a necessary adjunct to the tables. The latter are intended, in part, to enable students of the forest, lumbermen, and others to ascertain the volume of standing Pine per tree and per acre, in cubic and board feet, much more easily and accurately than has hitherto been possible, and to predict its increase in the same units for any desired number of years. By the use of these tables the relations between growth, interest on capital invested, and current expenses (such as taxes) cease to be matters of conjecture, and become susceptible of easy calculation. Many other uses of the tables will be developed in the course of the discussion.

The tables and silvicultural notes are based on measurements and other data obtained in central Pennsylvania and northern New York. The measurements of first- (or original-) growth White Pine were all made in Pennsylvania, and

in localities where lumbering operations were in progress, so that the figures could be collected as the trees were felled and sawed into logs. Thus a large number of measurements were taken on Lick Run, Clearfield County, in the Pine Creek district of Lycoming County, and in a large windfall on Naval Run, a short distance above Slate Run station, in Tioga County.

The notes on the second-growth Pine were taken in Pennsylvania upon the high plateau south of Driftwood, Cameron County, near Ansonia in the Pine Creek district of Tioga County, and in Lycoming County on the plateau above Otter River. Valuation surveys of a few groups in Franklin and Clinton Counties, New York, were used in the preparation of the yield tables.

The localities where the data were obtained varied in altitude from a few hundred to nearly two thousand feet above the level of the sea. A more detailed description of the habitat of the White Pine in central Pennsylvania will be found farther on.

It should be noted that the area where the measurements were taken is comparatively restricted, and that the number of trees examined is not large in comparison with that used in the construction of tables for certain European trees. Nevertheless the scope of this study is

sufficient for the purpose in hand, and the correctness of its results is indicated both by their normal character and by reference to independent measurements in board feet. It is confidently believed that they will be found to be reliable not only for the region where they were obtained, but also for other portions of the habitat of the White Pine.

The point on the trunk of a tree hereafter indicated as "breast-high" is four and one half feet from the surface of the ground.

The White Pine (*Pinus strobus, Linnæus*) in cultivation abroad bears the name of Weymouth Pine, after Lord Weymouth, who planted it in quantity at Longleat in Wiltshire, shortly after its introduction into England in 1705, and afterward distributed the seed.

I

GROWTH

It is said that the very old and mature White Pine, called Pumpkin Pine by the lumbermen, has been almost entirely removed from the forests of Pennsylvania. Those old trees which remain are known under the name of first-growth or original Pine. They are characterized, especially when growing pure in crowded woods or in mixture with Hemlock, by great height and long, clean shafts, and they yield timber of the finest quality. This first-growth timber is for the most part from 200 to 250 years old, although trees of over 300 years occur. One magnificent specimen among the trees whose age was ascertained was found to be 351 years old. It was still perfectly sound. The dimensions of this tree are worth noting, since it is the largest Pine measured in the course of this investigation. They are: diameter at 4½ feet from the ground, 42 inches; total height, 155 feet; length of merchantable log, 114 feet. The total volume of the stem was 574 cubic feet, and it scaled 3,335 feet board measure of merchantable lumber.

The height of the great majority of old trees measured was between 100 and 120 feet, and the diameter was from 20 to 30 inches.

In these mature trees the percentage of wood which cannot be cut into logs is comparatively small. In most cases logs are considered merchantable which have a diameter of 8 inches at the small end. Very often logs are taken down to 7 inches at the top, or, in the suppressed trees, which are almost without branches, even to 6 inches. The stumps are, on an average, about two feet above the level of the ground. The spread of the roots below this point is so great, and the difficulty and expense of cutting close to the ground on steep slopes so serious, that in most cases a shorter stump is out of the question.

Up to a certain point the percentage of merchantable timber in a tree increases with the diameter. From a study of trees over 100 years old, the following figures were obtained:

Diameter breast-high, in inches.															
10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
Percentage of merchantable timber, excluding bark and branches.															
84.5	87	89	90	91	91.5	92	92.5	93	93.4	93.7	94	94	94	94	94

It appears from this table that only 6 per

cent. of the wood in a trunk 40 inches in diameter breast-high is left in the forest as waste, while a tree ten inches in diameter loses more than two and a half times as much, under the same conditions. It may also be seen that the percentage of merchantable timber does not increase after the diameter has reached 32 inches, and that even at 26 inches it is within 1 per cent. of its highest point.

The length of the crown, or that part of the whole stem upon which live branches are growing, varies according to the situation of the tree. A Pine standing in the open, with plenty of light and growing space, has, as a rule, a very large, full crown. On the other hand, when trees occur in crowded groups the spread of the top is hindered, the lower branches die for want of light, and the crown becomes narrow and short. The average length of crown of Pines over 100 years old growing in dense groups varied from 15 to 35 per cent. of the total length of the tree. For the same trees the length of shaft clear of all branches, alive or dead, was from 50 to 80 per cent. of the total length.

When trees grow in crowded groups the growth in diameter is reduced, and the height growth, to a certain limited extent, is increased. Such trees yield a better product not only be-

cause of the long clean boles; the wood itself is of greater density and strength. This may be explained as follows:

In the annual rings of trees two zones of wood may be distinguished. These are the spring wood, which is formed in the first part of the growing season, and is composed of large thin-walled wood cells, and the autumn wood, formed in the latter part, and made up of thicker-walled cells radially compressed. The spring wood is consequently the weaker, lighter, and softer of the two, since it is made up of cells which bear this character. The chief function of the spring wood is to conduct water from the roots to the crown. The autumn wood, while to a certain extent it also serves as a water-channel, has for its chief function to strengthen the stem. The larger the crown of a tree, and therefore the larger the evaporating surface in the leaves, the greater will be the demand for water, and consequently the greater the need for water-conducting organs. On the other hand, when trees grow in crowded groups, the crowns are smaller, the need for water-conducting organs is less, and the proportion of autumn wood is larger in the stem. The timber of the whole tree is therefore denser, stronger, and far less apt to rot.

This view is fully confirmed by our observa-

tions, for those trees which first showed decay at the butt were in almost all cases standing in open positions, with very large crowns, broad annual rings, and porous wood; while the old timber in dense groups mixed with hemlock was remarkably free from disease.

On the other hand, the wood of old trees which have grown rapidly and homogeneously possesses qualities of preëminent value for certain uses.

The lumber length of a tree increases with the diameter. In the table which follows the lumber length is regarded as the length from the level of the ground to the uppermost end of the merchantable timber, which was taken at the point determined by the actual practice of the lumbermen in each case. For the sake of convenience in determining the lumber length of standing trees the stump has been disregarded.

Diameter breast-high, in inches.															
10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
Lumber length, in per cent. of total length.															
68.3	72	75.2	77.2	79	80.5	81.5	82.3	83	83.5	84	84.5	84.8	85	85.3	85.5

This table presents in another form the relatively smaller loss from trees of large diame-

ter under the present demands of the market. A glance at it shows that, while over 85 per cent. of the length of a tree 40 inches in diameter is valuable for lumber, the proportion falls to 80.5 per cent. at the diameter of 20 inches, and to 68.3 per cent. when the diameter is only 10 inches. The comparatively slow increase of the percentage of lumber length after a diameter of 20 inches has been reached is interesting in connection with the slow rate of height growth in old trees.

The thickness of bark on the White Pine varies with the situation, among trees of the same age, and is different on different sides of the tree. Pines standing in the open have thicker bark, as well as a larger diameter and thicker sap-wood, than those in crowded woods. On old trees the bark is often exceedingly thick. A conspicuous instance is supplied by the very old tree already mentioned. Its bark measured 3.8 inches on the stump, whereas the average thickness for first-growth Pine is between one and two inches. On suppressed trees two hundred years old it is frequently as little as half an inch.

In trees over one hundred years old the bark varies from 9 to 12 per cent. of the total volume, and reaches an average of 11 per cent.

Upon trees fifty years old the average is 13 per cent. Upon very young trees the bark is thin and tender, and easily injured, especially by fire.

When a Pine is first cut there is little or no difference in the color of the sap- and the heart-wood. But upon exposure the heart-wood becomes reddish-brown, because of the oxidation of foreign matter stored in the walls of the wood cells. The separation between the heart- and the sap-wood is, however, clearly distinguishable on a White Pine stump, on account of the large amount of pitch which oozes from the sap-wood almost immediately after the tree is felled.

The number of annual rings in the sap-wood increases with the age of the tree. The following table shows the average for the trees measured in Pennsylvania:

Age.								
50	75	100	125	150	175	200	225	250
Number of annual rings in the sap-wood.								
17	22	25	29	32	35	37	40	42

It has been said that trees in the open have a broader sap-wood at the same age than those

in dense forests. That it is absolutely wider in such cases is usually true. But the diameter also is apt to be greater, and the proportion between its width and that of the sap-wood is not greatly changed. In general it is true that the percentage of the whole width included in the sap-wood decreases with the increase in diameter. The following table gives the average values for trees over 100 years old:

Diameter breast-high, in inches.															
10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
Width of sap-wood on the stump, in per cent. of the whole diameter.															
15.1	14	13	12	11.1	10.3	9.6	8.9	8.3	7.8	7.2	6.7	6.2	5.8	5.3	4.8

The decrease from 15.1 per cent. at ten inches diameter to 4.8 per cent. at forty inches is strikingly regular.

Still more interesting and far more important is the relation of the sap-wood to the total volume of wood in the stem. We find that, with increase in the diameter of a tree, the percentage of sap-wood falls off. The following table gives the average values obtained for trees over 100 years old:

Diameter breast-high, in inches.														
10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
Volume of sap-wood, in per cent. of the total volume of wood.															
37	34	31.3	28.8	26.6	24.6	22.9	21.5	20.2	19.2	18.2	17.5	16.8	16.1	15.5	15

Since the best grades of lumber are required to be free from sap-wood, the figures in this table exhibit clearly one of the reasons why a better product is cut from large logs than from small ones. They show that in spite of the steady increase in the number of rings of sap-wood as a tree grows older, it forms a less and less important part of the whole bulk of the tree.

"First growth," or "original growth," is taken to apply to all trees standing on land which has never been cut over, or better, all trees whose growth (if injury by fire is excepted) has never been influenced by human action. All trees which have taken their origin from the seed of the original Pine are included under the term "second growth." Second growth which occurs in situations similar to those once occupied by the original Pine shows precisely the same character as the other at the same age. That which springs up on good soil in the valleys and on the lower

slopes of the mountains is very rapid in growth, as the annual rings of the original Pine show it to have been at a corresponding period. There is every reason to believe that this second growth, if allowed to continue its development under like circumstances with the first growth, will eventually be just as valuable. But at present the sap-wood is broad, and hence the name Sap Pine is given to the trees.

Upon entering a group of young Sap Pine the attention is first attracted to the scrubby, knotty trees with heavy tops, while the small-crowned, long-boled trees may be overlooked by the casual observer. These large-crowned trees are advance growth, usually several years older than the main crop. The latter is often disregarded altogether, and an unfavorable opinion of the second growth is based on trees which do not properly form a part of the forest.

II

SITUATION AND OCCURRENCE

THE original Pine which still remains in those parts of Pennsylvania covered by this investigation is found in limited quantities at the heads of the smaller streams and runs, and in the more inaccessible parts of the mountains. A magnificent growth of White Pine once covered the slopes of the mountains and the sides of the ravines, overshadowing and enclosing the smaller streams, and attaining its best development about their headwaters. It spread completely over many of the mountains, growing in mixture with Hemlock, or, in places, nearly pure. Upon the best soils various hardwoods grew with it. Many of the steep slopes, where the soil is naturally poor and stony, are either absolutely bare, or covered with a growth of shrubs and worthless hardwoods, and capable of being reclaimed only after many years.

The old White Pine which furnished the data here employed was found upon the slopes of narrow, deep ravines, and at the heads of streams. It grew in mixture with Hemlock on

southern, western, or southwestern aspects; but became subordinate to the latter on the cooler slopes. In many cases White Pine was also found in abundance on northern slopes, but not as a rule.

The bottoms of the deep ravines where the White Pine grows are usually occupied by Hemlocks, or such hardwoods as Yellow Birch, Chestnut, and Red Maple, with an occasional Ash, and rarely a Yellow Poplar. Where the slope is very long and broken by a series of benches or small table-lands, the latter are often covered with Oaks and Chestnut, while the slopes themselves are clothed chiefly with Pine and Hemlock. At the top of the slopes the White Pine stops suddenly, and upon the very summit of the mountains, on poor soil, the Jack Pine usually takes its place. The Pitch Pine, as it is elsewhere and better named, grows, in many cases, to be a large, tall, clear-shafted tree, and yields admirable timber for mine-props. At the heads of the runs the White Pine extends further back upon the mountain-tops, and often occurs scatteringly with the Jack Pine.

The soil on these slopes is derived, for the most part, from the disintegration of sandstone, and varies from coarse white sand to loamy

sand, and in the better parts to sandy loam. The slopes are generally covered with flat sandstone rocks. When the forest is removed, and the fires run over the ground, the little soil that once existed is burned and washed away, and a barren mass of rocks is left to receive the seed of the few straggling unsound trees left standing by the choppers. In the valleys and on many of the mountain-tops, where the soil is a fresh sandy loam, uncultivated and unpastured land is almost immediately clothed with a forest growth of Pine and hardwoods. In such soils the White Pine attains an admirable development.

The remark may here be made that the White Pine, in favorable localities, retains its growth to a great age. Thus a number of trees standing on good soils were measured, and found to be growing in height four to five inches a year at the age of two hundred years. These trees were still adding to their volume from 1.3 to 1.5 cubic feet of wood per annum. In one case a tree was found to be growing at the rate of nearly two cubic feet of wood annually at two hundred years of age.

In general, White Pine thrives on a great variety of soils. It is found on the poorest, driest sand, on steep, rocky slopes, on the rich

vegetable earth of hollows and ravines, and again on moist clay flats and river bottoms. A strip of second-growth Pine frequently occurs on the brow of a hill from which old timber has been removed. Similar bodies are often found near the tops of slopes, sometimes on very poor soil. Upon better soils, where hardwoods were formerly mixed with the Pine, they take its place, at least for a time. The indications are very strong that the Pine, if left to itself, will at length resume possession of practically all the situations it occupied in the virgin forest.

Old clearings and abandoned pastures, if they can be reached by the winged, wind-blown seed of some old tree, grow up at once with an incipient forest of young Pines.

It results from this ability of the Pine to conquer new situations and resume possession of the old that the danger of its extinction as a timber tree in Pennsylvania is serious only on account of fire. The exhaustion of the supply of old trees must not be taken to mean the destruction of the species. We have already seen that second growth in good situations does not differ at all in individual development from the trees of the original forest at the same age in similar places. The future of White Pine in Pennsylvania, even with mediocre protection,

and under almost any kind of management short of the worst, is very full of promise. That its present treatment fails to meet either of these moderate conditions is obvious.

The young seedlings bear a good deal of shade provided they have germinated and grown under the cover of older trees. Those which have started in the open, on the other hand, are easily overgrown and killed by hardwood sprouts and fast-growing hardwoods from the seed. Many seedlings of White Pine were found suppressed and dying in these circumstances at the age of about twelve to fifteen years. Other seedlings, on the contrary, under the cover of dense Pine and Hemlock woods, were alive and struggling even among the mountain Laurel. Where some side light reaches the plants, they withstand a large amount of shade from above. One frequently sees young seedlings growing on decayed logs or stumps, or starting in the thick moss upon the rocks, extending their roots in search of the soil below. In open spots, along roadsides, and in old pastures and deserted fields, young growth is very common.

It is probable that in only a few cases do those plants recover which had stood in dense shade, and have been suddenly exposed to the whole

effect of the sun and wind by the removal of the crop overhead. Their leaves are undeveloped, and cannot perform the necessary assimilative functions under the changed conditions; nor are the plants themselves adapted to resist the drying action of the sun and wind.

A tree produces a full crop of seed when by the processes of its growth it has stored up in its cells a sufficient supply of digested plant food to furnish raw material for the fruit, when its blossoms succeed in ripening, and when other conditions, less clearly understood, are also favorable. When these things happen to a considerable proportion of any species in a forest at the same time, a seed-year is said to take place.

From a study of several hundred seedlings it appears that the White Pine bears seed on an average once in from 3 to 5 years, but that no regular interval exists between seed-years. The occurrence of a heavy crop of seed in 1892 is recorded in the numerous seedlings of that year which carpet the openings and the edges of the woods. A great deal of seed ripened about 1840, for much of the second-growth Pine in Pennsylvania, as well as in a number of other States, dates from that time. It is only possible, from our limited observations, to say that full seed-years occur only at long intervals.

Trees in the open, it is well known, bear seed more frequently and in greater abundance than those in crowded groups, a fact evidently connected with their ampler crown and more numerous leaves.

III

WHITE PINE IN MIXTURE

WHITE PINE is seldom found perfectly pure in Pennsylvania, except on very limited areas. It is a general law that in the original forest a much greater variety of species occurs on the best than on the poorer soils. Thus, in the Sap Pine groups of the valleys there is a much larger number of species in mixture with Pine than in the original groups on the poorer soils of the mountains.

The species which occurs most commonly mixed with the White Pine in Pennsylvania is the Hemlock (*Tsuga canadensis, Carr.*). It forms a lower story under the Pine, the shorter height classes of which it equals in length. Seen from above or from a distance, such a mixed group appears densely stocked with Pine, whereas, upon entering the wood, Hemlock seems to predominate. The Pine stretches above the Hemlock, and although it hides the latter at a distance, it is not noticed at first from below. Once the difference has been perceived, the dark reddish-brown bark of the Hemlock contrasts

strongly with the ashen-gray bark of the old Pine.

The Hemlock is of very slow growth, and remains behind the Pine from its youth up. But it withstands much more shade than the latter, one result of which appears in its longer crown, and it continues to flourish under cover until finally it grows up among the Pine and clears it of its lower branches. This most useful result follows chiefly from the extreme sensitiveness of the lower branches of the Pine to any shade, and is accomplished to the height of the Hemlock.

In dense old groups of Hemlock young growth is often found still thriving, but growing very slowly. This tree prefers northern and eastern slopes and cool situations. It reproduces itself easily. Young growth could be secured at will under forest management. Young seedlings are abundant even under very dense shade.

Where the two occur together the practice of Pennsylvania lumbermen is to cut the Pine the first year, and the Hemlock in the following season.

It is said that the Hemlock, if it is allowed to stand, dies off within a few years after the removal of the Pine. That this frequently happens is true. It is accounted for partly by the sudden exposure of trees which have stood for

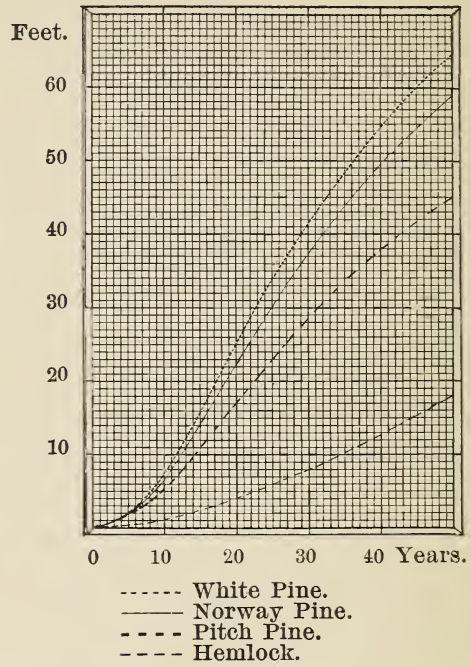
years in the shade under the protection of an upper story of White Pine, and partly by the drying out of the roots. The Hemlock has a shallow root system, and suffers severely when the soil about it is dried by exposure to the sun and wind. The same facts explain part of the injury to Hemlock by strong surface fires, an injury which could be avoided under forest management.

It is easy to see how the Hemlock, in these old forests, might gradually replace the Pine through the operation of its wonderful capacity to endure shade. There are comparatively few Pine seedlings in such dense groups, whereas young Hemlock occurs in abundance. After the old Pine veterans die off it seems likely that the Hemlock will remain. In all probability the many pure or nearly pure Hemlock groups in these mountains originated through the survival by the Hemlock of one species after another, because of its great shade-bearing powers. That bodies of Pine occur on land which the Hemlock would tend to occupy to its exclusion is often to be explained by the fact that, although it may once have been driven out, the Pine has returned in the windfall clearing made by a storm. The same result would follow a devastating fire. Such accidents

exert an undoubted influence on the mixture and topographic distribution of species.

Hemlock lumber is of great commercial importance in Pennsylvania, and is rapidly gain-

FIG. 1.



ing ground. A study of the silvicultural character of the tree, and the construction of yield- and volume-tables for it, would probably be of much use. Since nearly pure Hemlock forest exists over large areas, the construction of such tables would present no difficulty.

Of other coniferous trees, growing with White Pine in Pennsylvania, the Jack or Pitch Pine (*Pinus rigida, Mill.*) is the most common. It inhabits poor soils on the tops of ridges and on high plateaus. It requires a great amount of growing space, and regularly establishes itself in open groups. In intimate mixture with White Pine it is usually suppressed before reaching the age of fifty years. Occasionally it occurs in patches within White Pine groups. The ground under the Pitch Pine woods is almost always badly covered with shrubs and forest weeds. Thriving as it does upon the very poorest of soils, and withstanding fire better than any other tree of the region, the Pitch Pine abundantly deserves the attention of foresters.

The Norway or Red Pine (*Pinus resinosa, Ait.*) resembles the White Pine in many respects. It occurs only scatteringly in the sections of Pennsylvania under consideration. In rapidity of growth it is not far behind the White Pine, and it is further characterized by the production of excellent timber and a very straight stem.

Yellow or Scrub Pine (*Pinus virginiana, Mill.*), was found so sparingly that no study of its growth was made.

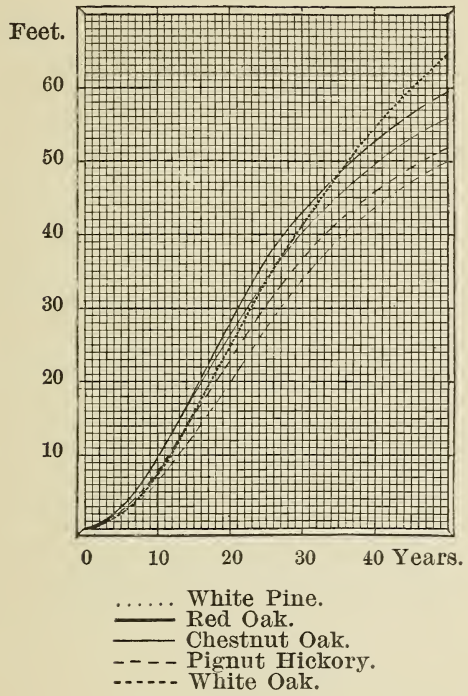
The Oaks are the most important hardwoods growing with the Pine, and of these the White Oak (*Quercus alba, L.*) demands most attention. Its qualities are too well known to require enumeration. Its growth is much slower than that of the White Pine, and where it occurs in mixture with Pine it is, as a rule, somewhat older. The Pine then serves to force the height growth of the White Oak, and in such cases we find it, as well as other hardwoods, producing long clean trunks. White Oak occurs on all kinds of soil, even growing with the Rock Oak on steep rocky slopes. It is a common tree on the plateaus.

Red Oak (*Quercus rubra, L.*) and Black Oak (*Quercus velutina, Lam.*) are found in mixture with White Pine only on the better class of soils. The rate of growth of the two species was nearly the same, and for both it was better than that of the Rock Oak or White Oak.

The Rock Oak or Chestnut Oak (*Quercus prinus, L.*) is intermediate in rapidity of growth between Black Oaks and White Oak. It reaches its best development on rich ground, yet occurs in abundance on poor soils, and is found mixed with Pine and Hemlock on steep rocky hills, of which it is a characteristic tree.

Hickory occurs but sparingly with White Pine, and then only on the best soils. White

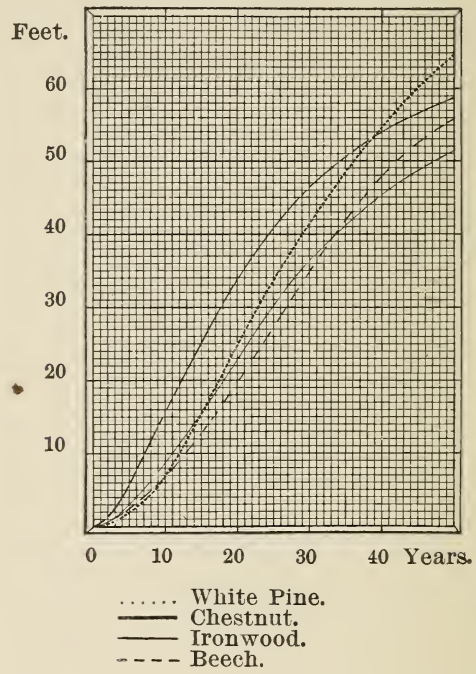
FIG. 2.



Hickory (*Hicoria ovata, Britt.* [*Carya alba, Nutt.*]) showed a slightly better growth than Pignut Hickory (*Hicoria glabra, Britt.* [*Carya porcina, Nutt.*]), as far as was observed.

The Chestnut (*Castanea dentata, Borck.*) is found abundantly with White Pine on both good and very poor soils. Its growth in youth is very rapid.

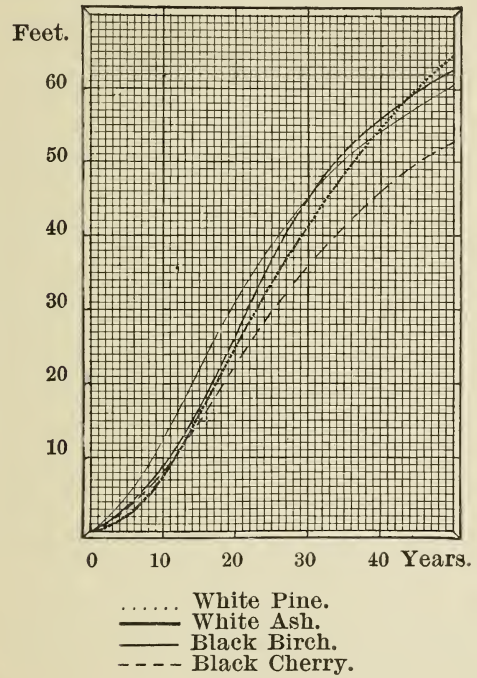
FIG. 3.



Yellow Birch (*Betula lutea, Michx. f.*) is found in the bottoms of the ravines, and on good soils. Black Birch (*Betula lenta, L.*) and White Birch (*Betula papyrifera, Marsh.*) also occur.

One of the commonest species growing in mixture with White Pine, in all situations and on all kinds of soil in central Pennsylvania, is the Red Maple (*Acer rubrum, L.*). On good

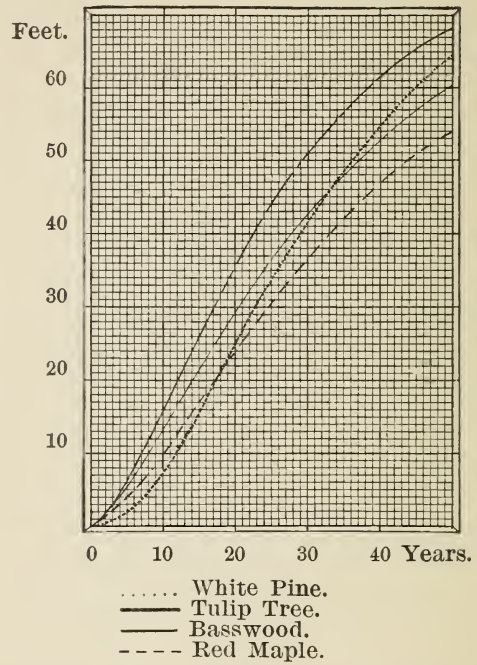
FIG. 4.



soils Rock or Sugar Maple (*Acer barbatum, Michx.*) is also found. Its rate of growth is at least equal to that of the Red Maple, which it far surpasses in economic value.

At a place in Lycoming County near Otter Run an astonishingly large number of kinds of trees occurred on a fresh sandy loam in mixture

FIG. 5.



with White Pine. Upon an area of not more than twenty acres the following species were growing in natural forest:

Yellow Poplar (*Liriodendron tulipifera, L.*).
Basswood (*Tilia americana, L.*).
Sugar Maple (*Acer barbatum, Michx.*).
Red Maple (*Acer rubrum, L.*).
Pin or Wild Red Cherry (*Prunus pennsylvanica, L. f.*).

Wild Black Cherry (*Prunus serotina, Ehrh.*).
Black Gum (*Nyssa sylvatica, Marsh*).
White Ash (*Fraxinus americana, L.*).
Slippery Elm (*Ulmus fulva, Michx.*).
Butternut (*Juglans cinerea, L.*).
Bitternut Hickory (*Hicoria minima, Britt.* [*Carya amara, Nutt.*]).
White Hickory (*Hicoria ovata, Britt.* [*Carya alba, Nutt.*]).
Pignut Hickory (*Hicoria glabra, Britt.* [*Carya porcina, Nutt.*]).
White Oak (*Quercus alba, L.*).
Chestnut Oak (*Quercus prinus, L.*).
Red Oak (*Quercus rubra, L.*).
Black Oak (*Quercus velutina, Lam.*).
Chestnut (*Castanea dentata, Borck.*).
Beech (*Fagus ferruginea, Ait.*).
Hop Hornbeam (*Ostrya virginiana, K. Koch.*).
Hornbeam (*Carpinus caroliniana, Walt.*).
White Birch (*Betula papyrifera, Marsh.*).
Yellow Birch (*Betula lutea, Michx. f.*).
Black Birch (*Betula lenta, L.*).
Quaking Asp (*Populus tremuloides, Michx.*).
Poplar (*Populus grandidentata, Michx.*).
Norway Pine (*Pinus resinosa, Ait.*).
Pitch Pine (*Pinus rigida, Mill.*).
Yellow Pine (*Pinus virginiana, Mill.*).
Hemlock (*Tsuga canadensis, Carr.*).

The following table gives the average height growth for a few of these species based on a comparatively small number of measurements. The trees were all growing on soil of the first grade for White Pine. It must be remembered that this table does not represent a thorough study of the trees in question, but results from

the measurements of a restricted number of specimens growing in mixture with the Pine. These values are graphically represented in the figures by means of curves.

SPECIES.	AGE.				
	10	20	30	40	50
	HEIGHT IN FEET.				
White Pine	7.4	25.0	41.5	54.5	64.5
Norway Pine	6.6	22.3	37.3	49.5	59.0
Pitch Pine	5.3	17.0	28.6	38.0	45.0
Hemlock	1.1	4.0	8.0	12.9	28.0
Red Oak	9.8	28.0	43.0	52.7	59.4
Chestnut Oak	9.8	26.3	40.3	49.6	55.9
White Oak	6.5	20.0	34.0	43.7	49.9
Pignut Hickory	7.9	23.0	36.9	45.9	51.8
Chestnut	15.6	33.8	46.3	54.0	58.8
Beech	6.9	19.9	34.9	47.9	55.9
Ironwood	8.9	22.8	36.4	45.3	51.3
White Ash	9.0	26.3	45.0	56.0	62.6
Black Birch	12.5	31.0	45.0	54.1	60.5
Black Cherry	8.1	22.5	36.0	46.0	52.8
Tulip Tree	15.7	35.4	51.0	61.5	68.1
Basswood	13.1	29.1	42.6	52.8	60.3
Red Maple	9.8	23.9	36.5	46.9	54.0

IV

FIRE AND WIND

THE worst enemy of the Pennsylvania woodlands, and especially of the coniferous forests, is fire. Very few of the Pine woods visited in the course of this investigation were without traces of it. Although many of the fires run only upon the surface and do no direct harm to the timber itself, the indirect injury which results from burning the humus layer and drying out the soil is very serious, and should not be overlooked. Such fires are often followed by a decrease in the rate of annual growth from which it may take the trees several years to recover. In very many other cases the injury to the tree is both direct and important. Often the bark of the butt is scorched or burned, and the cambium layer below it killed by heat. Then the bark loosens or drops away, and decay sets in soon afterward.

When exposed to fire the young growth, with its delicate bark and foliage, is killed at once. Later on, when the trees have reached an age of forty to sixty years, and have formed thick

corky bark, many of them are comparatively safe from direct injury from moderate surface fires. But if a fire reaches the crown and burns the leaves, the tree does not survive. Large bodies of second-growth Pine were examined which had been killed in this way.

After lumbering the danger from fire is very great, and especially where Hemlock has been cut, because of its heavy crown and great quantity of fine spray. As the tops lie on the ground, a large surface is thus exposed to the action of the wind and sun, and the whole mass becomes exceedingly inflammable. The crown of the Pine, on the other hand, is not only shorter, but it is generally very much broken by the fall of the tree. It furnishes, in consequence, far less material to feed a fire. It may be said in passing that a very considerable source of danger would be removed if it were possible for lumbermen to break down the tops of lumbered trees. Standing, as they often do at present, propped clear of the ground on their leg-like branches, they become as dry as tinder and burn with an intense heat. The danger lasts long, for the tops rot very slowly. If they could be brought in contact with the ground their menace to the forest would speedily disappear.

In the spring, under the influence of the warm

dry southwest wind, fires are easily started. They burn most readily, and are most frequent, on south and southwest slopes, and upon mountain-tops and ridges. Fires running down hill are often stopped by the damp moss and other vegetation under the dense cover of Hemlock and Pine. When started at the bottom of a slope, a fire may either run up over the hillside or it may follow some narrow ravine, which acts almost like a chimney to increase its power.

The chief causes of fires are the desire for better pasture or a richer crop of huckleberries, the carelessness of campers, recklessness in clearing land or burning a fallow, railroads, and malice. The country is so sparsely populated that, even when the incendiary is known, it is practically impossible to secure evidence sufficient to convict.

The usual method of fighting fires is backfiring, but the scanty population makes it both costly and difficult, in most lumber regions, to assemble men enough to offer successful resistance to extensive fires. Effective measures must look toward localizing the danger by cutting fire-lines, and the organization of systems of fire wardens or fire patrols. But these precautions are expensive, and without a strong public sentiment behind them they can

never fully succeed. When the inhabitants of any region where fires occur become thoroughly alive and earnest in the desire to prevent and extinguish them, then the danger from that source will be in a fair way to disappear.

White Pine is fairly wind-firm; much more so than Hemlock. Still it is often thrown by tornadoes and extraordinarily strong winds. In such cases lumbermen peel a strip of bark from the top of the stem throughout the lumber length. The rest of the bark becomes loosened and falls off, and the wood is saved from the attacks of borers.

V

VOLUME-TABLES

During the few months spent in taking measurements of the White Pine 160 trees were completely analyzed. In addition, some 60 specimens of other species growing in mixture with the White Pine were measured in order to obtain the course of the growth of height. The method of tree-analysis was as follows:

After each tree was felled and cut into logs, the following measurements were taken:

Distance of each cut from the ground.

Total length.

Length of the green crown.

Lumber length.

Clear length.

Number of logs actually taken in practice.

Thickness of the bark at each cut.

Age and width of the sap-wood at each cut.

Number of annual layers at each cut, counting inward from the bark on an average radius, and marking each ten-year point.

Distance from the periphery to each ten-year point.

Average diameter inside the bark.

Note was made of the health of the tree, the character of the crown, the relative size of the tree in comparison with the trees about it, the character of forest in which it stood, and the soil and situation.

In order to obtain the total age of a tree, the number of years required by the young tree to grow to the height of the stump must be added to the number of rings counted on the latter. To this end, a large number of young seedlings were cut and measured in each locality, and the number of years was ascertained which the young tree required to grow one, two, or three feet, or whatever the height of the stumps in question may have been.

In calculating the volume of the tree, the branches are neglected, and only the stem is taken into account. Each section is treated as a frustum of a paraboloid and cubed by the formula

$$V = (M + m)\frac{h}{2},$$

where V is the volume, M and m the areas of the circles at the ends of the sections, and h the length of the section.

The top section, the volume of which is al-

ways a small fraction of a cubic foot, is treated as a cone, and cubed by the formula

$$V = \frac{M \times h}{3},$$

where V is the volume, M the area of the last cut, and h the length of the last section.

The stump is also included in the calculation of the total volume, but the flare of the roots is left out of account. The diameter at the ground is regarded as the diameter on the stump plus the diameter of the young seedling whose height is the same as that of the stump, and whose age is the number of years required for the seedling to grow to the height of the stump.

The values in board feet were calculated by means of measurements taken at the small end of each log, from tables constructed by Doyle's Rule, the common standard of the region. According to this rule the number of board feet in a log 16 feet long is found by subtracting 4 from the diameter inside the bark at the small end, expressed in inches, and squaring the result. Thus a 16-foot log 24 inches across the upper end inside the bark would contain 400 feet board measure, because $24-4=20$, and $20\times20=400$. This rule is intended to give the quantity of square-edged one-inch boards which may be

sawed from a log. It is a safe guide for sawmill men, and it underestimates the possible number of feet, especially for logs of small diameter.

The volume tables are constructed only for trees over 100 years old. As material for these tables we have the analyses of over 100 trees. From the analysis it is possible to compute the volume of a tree at successive ten-year periods during its whole life. Thus, in the case of a tree 200 years old, we can calculate its volume when it was 100, 110, 120, 130, . . . 190, 200 years old. Consequently, for the construction of the tables we have the equivalent of eleven trees instead of one.

It must be remembered that the volume tables represent average values of trees taken from all qualities of soils and localities, and that they are intended chiefly for use in computing the volume of large groups.

A form factor, or coefficient of form, is the relation between the volume of a tree and the volume of a geometrical solid of the same diameter and height as the tree. It represents the taper of the tree. In this case the solid is a cylinder, and the form factor is a number by which the volume of a cylinder which has the same base and height as the tree must be mul-

tiplied in order to obtain the volume of the tree.

On account of the taper, the volume of the tree will be less than that of the cylinder, and therefore the form factor will be a decimal.

If a is the area of the base, or the area of the circle corresponding to the diameter, the so-called basal area;

h the height of the tree;

V the volume; and

f the form factor; then

$$V = a \times h \times f; \text{ or } f = \frac{V}{a \times h}$$

In this way the form factor was calculated for each tree; the stem alone, with the bark on, being taken into account.

With the increase of diameter the form factors decrease. With trees of the same diameter no variation in the form factors occurred with increase in height sufficiently regular to permit the formulation of a law. It was necessary, therefore, to accept the average value of all the different heights corresponding to each diameter.

The form factors are given in the right-hand column of Table I, and are seen to vary from .508 to .420 as the diameters grow larger. There is at first a slight increase to .512, and

then a regular falling off. The form factors for the bigger trees are rather large. The latter, in nearly all cases, were standing in full enjoyment of light and growing space, and their trunks had correspondingly little taper. Furthermore, the largest trees are some 250 years old, while the smallest are from 100 to 150 years younger.

The values in Table I were obtained by the use of the form factors. The volume in each case is equal to the product of the basal area by the height multiplied by the form factor corresponding to the diameter of the tree.

In order to test the accuracy of the form factors, the trees actually measured were thrown into diameter classes of two inches, and the average heights were obtained for each diameter class by means of a plotted curve. The volume was then computed by the use of the form factors, and the result compared with the actual measured volume of the trees. The error was only 2 per cent.

Volume Tables for White Pine calculated for the whole contents of the stem with and without bark in cubic feet, and for the merchantable timber in cubic and board feet, together with form factors for the stem with bark.

TABLE I

VOLUME TABLE FOR WHITE PINE

Diam. breast-high. Inches	HEIGHT OF THE									
	65	70	75	80	85	90	95	100	105	110
	CONTENTS OF THE STEM									
10	18.0	19.4	20.8	22.1	23.5					
12	26.1	28.1	30.1	32.1	34.2	36.2	38.2			
14	35.4	38.1	40.8	43.5	46.3	49.0	51.7	54.4		
16		49.0	52.5	56.0	59.4	62.9	66.4	69.9	73.4	76.9
18			65.1	69.4	73.7	78.1	82.4	86.8	91.1	95.4
20				84.0	89.2	94.5	99.7	105.0	110.2	115.4
22				99.5	105.7	111.9	118.1	124.3	130.6	136.8
24					123.1	130.4	137.6	144.8	152.1	159.3
26						150.0	158.3	166.6	175.0	183.3
28							180.8	190.3	199.8	209.3
30								215.5	226.3	237.1
32										266.6
34										
36										
38										
40										

TABLE I

OVER 100 YEARS OLD

TREE IN FEET									Diam. breast-high. Inches	Stem Form Factor
115	120	125	130	135	140	145	150	155		
WITH BARK IN CUBIC FEET										
									10	.508
									12	.512
									14	.509
									16	.501
									18	.491
120.7									20	.481
143.0	149.2								22	.471
166.6	173.8	181.1							24	.461
191.7	200.0	208.3	216.6	225.0					26	.452
218.8	228.3	237.9	247.4	256.9	266.4				28	.445
247.8	258.6	269.4	280.2	290.9	301.7				30	.439
278.7	290.9	303.0	315.1	327.2	339.3	351.5			32	.434
311.1	324.6	338.1	351.6	365.2	378.7	392.2			34	.429
	360.5	375.5	390.6	405.6	420.6	435.6	450.6		36	.425
		415.6	432.1	448.7	465.3	481.9	498.5		38	.422
			476.5	494.8	513.2	531.5	549.8	568.1	40	.420

In the discussion of the bark it was said that, with a range of from 9 to 12 per cent., it averages 11 per cent. of the total volume of trees over 100 years old. The figures in Table II were obtained simply by taking 89 per cent. of the values in Table I.

TABLE II

VOLUME TABLE FOR WHITE

Diam. breast-high. Inches	HEIGHT OF THE									
	65	70	75	80	85	90	95	100	105	110
	CONTENTS OF THE STEM									
10	16.0	17.3	18.5	19.7	20.9					
12	23.2	25.0	26.8	28.6	30.4	32.2	34.0			
14	31.5	33.9	36.3	38.8	41.2	43.6	46.0	48.4		
16		43.6	46.7	49.8	52.9	56.0	59.1	62.2	65.3	68.4
18			57.9	61.8	65.7	69.5	73.3	77.2	81.1	84.9
20				74.8	79.4	84.1	88.7	93.5	98.1	102.7
22				88.6	94.1	99.6	105.1	110.6	116.2	121.8
24					109.6	116.1	122.5	128.9	135.4	141.8
26						133.5	140.9	148.3	155.8	163.1
28							160.9	169.4	177.8	186.3
30								191.8	201.4	211.0
32										237.3
34										
36										
38										
40										

TABLE II

PINE OVER 100 YEARS OLD

TREE IN FEET									Diam. breast-high. Inches
115	120	125	130	135	140	145	150	155	
WITHOUT BARK IN CUBIC FEET									
									10
									12
									14
									16
									18
107.4									20
127.3	132.8								22
148.3	154.7	161.2							24
170.6	178.0	185.4	192.8	200.3					26
194.7	203.2	211.7	220.2	228.6	237.1				28
220.5	230.2	239.8	249.4	258.9	268.5				30
248.0	258.9	269.7	280.4	291.2	302.0	312.8			32
276.9	288.9	300.9	312.9	325.0	337.0	349.1			34
	320.8	334.2	347.6	361.0	374.3	387.7	401.0		36
		369.9	384.6	399.3	414.1	428.9	443.7		38
			424.1	440.4	456.7	473.0	489.3	505.6	40

On page 5 the percentages of merchantable timber in the whole stem, without bark, are given for the various diameters. Table III is constructed from Table II by the use of these values.

TABLE III

VOLUME TABLE FOR WHITE

Diam. breast-high. Inches	HEIGHT OF THE									
	65	70	75	80	85	90	95	100	105	110
	MERCHANTABLE CONTENTS OF									
10	13.5	14.6	15.6	16.6	17.7					
12	20.2	21.8	23.3	24.9	26.5	28.0	29.6			
14	28.0	30.2	32.3	34.5	36.7	38.8	40.9	43.1		
16		39.2	42.0	44.8	47.6	50.4	53.2	56.0	58.8	61.6
18			52.7	56.2	59.8	63.2	66.7	70.3	73.8	77.3
20				68.4	72.7	77.0	81.2	85.6	89.8	94.0
22				81.5	86.6	91.6	96.7	101.8	106.9	112.1
24					101.4	107.4	113.3	119.2	125.2	131.2
26						124.2	131.0	137.9	144.9	151.7
28							150.3	158.2	166.1	174.0
30								179.7	188.7	187.7
32										223.1
34										
36										
38										
40										

TABLE III

PINE OVER 100 YEARS OLD

TREE IN FEET									Diam. breast-high. Inches
115	120	125	130	135	140	145	150	155	
THE STEM IN CUBIC FEET									
									10
									12
									14
									16
									18
98.3									20
117.1	122.2								22
137.2	143.1	149.1							24
158.7	165.5	172.4	179.3	186.3					26
181.8	189.8	197.7	205.7	213.5	221.5				28
206.6	215.7	224.7	233.7	242.6	251.6				30
233.1	243.4	253.5	263.6	273.7	283.9	294.0			32
260.3	271.6	282.8	294.1	305.5	316.8	328.2			34
	301.5	314.1	326.7	339.3	351.8	364.4	376.9		36
		347.7	361.5	375.3	389.3	403.2	417.1		38
			398.7	414.0	429.3	444.6	459.9	475.3	40

Table IV is the most important of the series for practical use. It was constructed from Table I in the manner explained in the paragraphs which follow.

Inasmuch as one board foot is a board one foot long, one foot wide, and one inch, or $\frac{1}{12}$ of a foot, thick, one cubic foot must be equal to 12 board feet of solid wood.

The actual measurements of the trees in board feet according to Doyle's Rule were thus reduced to cubic feet by dividing by 12, and the relation between the figures obtained and the total volumes of wood and bark given in Table I were computed. The result was as follows:

Diameter breast-high, in inches.															
10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
Board feet reduced to cubic feet, in percentage of the total volume of wood and bark.															
12	18	23	26	29	32	35	38	40	42	44	45	46	47	48	49

This table gives the percentage of loss in manufacturing lumber from the standing tree on the basis of the common standard of measure. It shows an accidental but appreciable relation between the diameter in inches and percentage of wood actually used in commerce at the different diameters. But its chief value is in exhibiting the enormous loss under the present

methods. Less than half the cubic contents of a White Pine forty inches in diameter reaches the market from the saws, and when the diameter sinks to ten inches, eighty-eight per cent. of the tree is lost. It should be repeated here that Doyle's Rule gives a much smaller number of board feet, in proportion to their cubic contents, to small logs than to larger ones, and that on the whole it tends to understate the possible lumber product from logs.

The values in Table I were multiplied by the percentages just given, and the results were multiplied by twelve, in order to convert them back to board feet.

The diameter and height of a tree being known, Table IV shows at a glance its merchantable contents. Where the height and the diameter must be estimated, as is usually the case, it furnishes an easy and accurate method of determining the equivalent of these estimates in board measure.

TABLE IV

VOLUME TABLE FOR WHITE

Diam. breast-high. Inches	HEIGHT OF THE									
	65	70	75	80	85	90	95	100	105	110
	BOARD FEET									
10	26	28	30	32	34					
12	56	61	65	69	74	78	83			
14	98	105	113	120	128	135	143	150		
16		153	164	175	185	196	207	218	229	240
18			227	242	256	272	287	302	317	332
20				323	343	363	383	403	423	443
22				418	444	470	496	522	549	575
24					561	595	627	660	694	726
26						720	760	800	840	880
28							911	959	1,007	1,055
30								1,138	1,195	1,252
32										1,440
34										
36										
38										
40										

TABLE IV

PINE OVER 100 YEARS OLD

TREE IN FEET									Diam. breast-high. Inches.
115	120	125	130	135	140	145	150	155	
BY DOYLE'S RULE									
									10
									12
									14
									16
									18
463									20
601	627								22
760	793	826							24
920	960	1,000	1,040	1,080					26
1,103	1,151	1,199	1,247	1,295	1,343				28
1,308	1,365	1,422	1,479	1,536	1,593				30
1,505	1,571	1,636	1,702	1,767	1,832	2,018			32
1,717	1,792	1,866	1,941	2,016	2,090	2,165			34
	2,033	2,118	2,203	2,288	2,372	2,457	2,541		36
		2,394	2,490	2,585	2,680	2,776	2,871		38
			2,802	2,909	3,018	3,125	3,233	3,340	40

VI

YIELD TABLES

NOTE has already been made of the fact that White Pine was very seldom found perfectly pure, and that when such groups occurred they were always very small in area. The groups for the valuation surveys were selected with as little admixture of other species as possible. Whenever it was feasible a full acre was measured; but in several instances where the Pine occurred in small patches the survey covered only three quarters of an acre.

The procedure was as follows: After staking off the area, the diameters of the trees were measured with calipers to the nearest inch. All diameter measurements were taken at 4½ feet above the level of the ground. The different species were entered in separate columns in the field-book. After a tree was measured, the bark was blazed with a gouge-blaze, in order that no mistake might occur by measuring it again.

The inch diameter classes were then arranged

in major classes, each major class containing, as a rule, four inch classes. The major classes were treated as separate groups, and the cubic content of each was obtained by means of a test tree.

The actual basal area, or the total area of the cross sections of all the trees breast-high, was computed for each major class, and this number was divided by the number of trees in the class. The product was the mean basal area of the class, or the basal area of the average tree. The diameter which corresponds to this area is the diameter of the average stem of the class.

A tree was then chosen, as a sample or test tree, which had the same diameter as this average tree. Care was taken that its height was normal, and that it was not abnormally full-boled or tapering. This tree was felled, and analyzed according to the method already described. The cubic content of each major class was then calculated as follows:

The cubic content of the whole class is to the cubic content of the test tree as the basal area of the whole class is to the basal area of the test tree. Or if

V is the volume of the whole class,

v the volume of the test tree,

A the basal area of the whole class, and
a the basal area of the test tree, then

$$V : v : : A : a$$

$$\text{or } V = \frac{v \times A}{a}$$

If, for example, a major class containing trees of 11, 12, 13, and 14 inches in diameter has a total basal area of 500 square feet, and its test tree has a basal area of 1 square foot and a volume of 25 cubic feet, then

v = 25 cubic feet
A = 500 square feet
a = 1 square foot

and $V : 25 : : 500 : 1$

or $$V = \frac{25 \times 500}{1}$$

$$= 12{,}500 \text{ cubic feet}$$

= the volume of the whole class.

The content of each major class being thus determined, their sum gave the contents of the whole group. In this way the total volume of each group, with and without bark, was ascertained, as well as the merchantable contents in cubic and board feet. Here, as in all calculations of volume in this study, branches were entirely excluded.

It would have been more accurate to measure a number of test trees for each major class instead of only one; but it was the aim to waste as little timber as possible in the investigation. Furthermore, this simple method is sufficiently exact for every practical purpose.

A careful description was made of the locality of each valuation survey, and the following points were noted:

a. The relative and absolute altitude.

b. The rock and soil.

c. The condition of the humus.

d. The surface growth.

e. The quality of the locality, which was given as I, II, or III, according as it was judged to be good, intermediate, or poor for the growth of White Pine.

f. The density of the forest crop. This last was expressed in decimals of 1. The density was judged mainly by the forest canopy — that is, if the cover was complete and the ground entirely shaded, there being no holes or blanks, the density was called 1. If there was only half a crop it was called 0.5. The density of White Pine and of all other species taken together was also determined independently.

The diameter of the average tree of a group, as we have seen, is found by dividing the total

basal area of the group by the number of trees. The result will be the basal area of the average tree, from which the diameter may easily be obtained. The average height and age of a group are the same as the height and age of the average tree.

Below is given a summary of the valuation surveys, in which the most essential points are noted. It will be seen that in most cases only the generic name is given, and that the names of the species in mixture are abbreviated. The abbreviations are as follows:

A. Ash
B. Birch
Bch. Beech
Ced. White Cedar (*Thuja occidentalis, L.*)
Ch. Chestnut
Cy. Black Cherry
Fr. Balsam Fir
Gm. Black Gum
H. Hickory
Hm. Hemlock
I. Ironwood (*Ostrya virginiana, K. Koch.*)
JP. Jack or Pitch Pine
M. Maple
NP. Norway Pine
O. Oak
Pop. Poplar
Sp. Spruce
Tu. Yellow Poplar or Tulip Tree

Descriptive table of the valuation surveys, with particulars of the Station Soil, and growing stock, the species in mixture, and the Density of the Forest.

State.	County.	Nearest Railroad Station.	SOIL.	
			Composition.	Consistency.
N. Y.	Franklin.	Brandon.	Sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Sandy loam.	Binding.
N. Y.	Clinton.	Cadyville.	Clay.	Binding.
Pa.	Lycoming.	Jersey Mills.	Sandy loam.	Binding.
Pa.	Lycoming.	Jersey Mills.	Sandy loam.	Binding.
Pa.	Lycoming.	Jersey Mills.	Sandy loam.	Binding.
Pa.	Lycoming.	Jersey Mills.	Sandy loam.	Binding.
Pa.	Tioga.	Ansonia.	Sandy loam.	Loose.
Pa.	Tioga.	Ansonia.	Sandy loam.	Loose.
Pa.	Tioga.	Ansonia.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.
Pa.	Cameron.	Driftwood.	Sandy loam.	Loose.

SOIL (*continued*).					
Moisture.	Humus.	Rock.	Slope.	Aspect.	Quality.
Dry.	Scanty.	Glacial drift.	Undulating.	.....	II.
Fresh.	Good.	Sandstone.	Flat.	.....	I.
Fresh.	Fair.	Shale.	Flat.	.....	I–II.
Fresh.	Good.	Sandstone.	Flat.	.....	I.
Fresh.	Good.	Sandstone.	Gentle.	N.	I.
Fresh.	Good.	Sandstone.	Flat.	.....	I.
Fresh.	Good.	Sandstone.	Flat.	.....	I.
Fresh.	Good.	Sandstone.	20°	S. W.	I.
Fresh.	Fair.	Sandstone.	15°	S.	I.
Fresh.	Good.	Sandstone.	10°	S.	I.
Fresh.	Burned.	Sandstone.	Flat.	.....	I.
Fresh.	Burned.	Sandstone.	Flat.	.....	I.
Fresh.	Fair.	Sandstone.	Flat.	.....	I.
Fresh.	Fair.	Sandstone.	Flat.	.....	I.
Fresh.	Fair.	Sandstone.	Flat.	.....	I.
Fresh.	Burned.	Sandstone.	Flat.	.....	I.
Fresh.	Burned.	Sandstone.	Flat.	.....	I.
Fresh.	Burned.	Sandstone.	Flat.	.....	I.
Fresh.	Burned.	Sandstone.	Flat.	.....	I.

GROWING STOCK OF WHITE PINE.

Average height. Feet.	Diameter of average tree. Inches.	Age.	Number of trees.	Basal area. Sq. Ft.	Volume, including bark. Cu. Ft.	Volume, without bark. Cu. Ft.	Merchantable timber. Cu. Ft.	Merchantable timber. Board Feet.
20.0	3.3	19	331	19.25	241.4	208.0	.....	.....
30.7	5.0	26	561	76.86	1,402.0	1,142.3	.....	.....
41.6	6.7	35	295	72.03	1,850.0	1,628.0	.....	.....
43.8	6.7	39	570	138.74	3,702.0	2,991.5	1,217.5	1,624
43.8	6.9	39	332	86.51	2,297.0	1,907.0	799.0	1,318
48.0	6.9	40	395	101.48	2,686.0	2,284.8	822.6	1,602
48.0	7.1	40	463	127.16	3,383.0	2,850.0	1,041.0	2,043
61.3	12.7	51	160	141.03	4,717.2	4,156.0	2,938.4	9,423
68.7	11.25	52	227	157.11	5,570.0	5,194.0	3,896.0	11,794
60.0	8.1	51	159	56.61	2,038.0	1,773.1	1,347.6	2,500
66.3	10.7	51	211	132.16	4,119.0	3,501.1	2,241.0	5,700
61.6	9.1	54	246	110.45	3,927.0	3,297.0	2,258.4	5,522
66.0	9.8	51	234	123.65	4,162.0	3,583.0	2,389.5	6,199
65.8	10.3	51	130	74.63	2,709.0	2,324.0	1,673.3	4,607
61.5	8.3	51	171	68.84	2,294.0	1,921.0	1,154.5	3,188
63.0	8.8	50	357	150.78	5,373.0	4,657.0	2,794.2	6,438
64.4	9.0	51	260	114.98	4,194.0	3,667.0	2,200.2	5,336
62.6	8.7	50	358	146.10	4,535.0	4,467.0	2,814.2	7,706
65.8	9.4	51	233	110.89	3,753.0	3,227.6	2,194.8	5,660

SPECIES IN MIXTURE.			DENSITY.		
Most important species.	Number of trees.	Basal area. Sq. Ft.	White Pine.	Other species	Holes and blanks.
.....	...	.....	0.3	.....	0.7
O., A., H., Ch.	36	6.56	0.8	0.1	0.1
.....	...	.....	0.65	.....	0.35
O., H., Ch., NP., JP.	55	12.29	0.8	0.1	0.1
O., A., Ch., M., H., B., I., Hm., NP., JP.	63	17.18	0.7	0.2	0.1
A., Cy., M., Pop., B., Gm., NP., Hm.	54	9.92	0.8	0.1	0.1
A., Ch., M., H., B., Bch., Cy., Tu., Hm., Pop.	81	12.84	0.9	0.1	.....
M.	3	1.87	0.85	.....	0.15
Hm., NP., B., Ch., M., Bch.	23	8.0	0.85	0.05	0.1
O., B., Bch., Ch., M., Hm., NP.	99	28.7	0.5	0.3	0.2
O., M., Ch., Cy., Pop., JP.	35	10.95	0.75	0.1	0.15
O., M., Ch., Pop., JP.	24	7.24	0.7	0.1	0.2
O., Ch., JP.	89	32.51	0.7	0.2	0.1
O., Cy., Pop., JP.	117	43.1	0.5	0.4	0.1
O., Ch., M., JP.	140	48.2	0.4	0.5	0.1
O., JP.	27	18.13	0.9	0.1	.....
O., Ch., Cy., Pop., JP.	27	12.15	0.7	0.1	0.2
O., Cy., Pop.	47	22.01	0.8	0.15	0.05
O., JP.	10	3.65	0.65	0 05	0.3

State.	County.	Nearest Railroad Station.	SOIL.	
			Composition.	Consistency.
N. Y.	Franklin.	Brandon.	Sand.	Loose.
N. Y.	Franklin.	Brandon.	Sand.	Loose.
N. Y.	Franklin.	Brandon.	Sand.	Loose.
N. Y.	Clinton.	Cadyville.	Clay.	Binding.
N. Y.	Clinton.	West Plattsburgh.	Sand.	Loose.
Pa.	Tioga.	Ansonia.	Sandy loam.	Loose.
Pa.	Tioga.	Ansonia.	Loamy sand.	Loose.
Pa.	Tioga.	Ansonia.	Loamy sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Sand.	Loose.
Pa.	Tioga.	Slate Run.	Sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Loamy sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Loamy sand.	Loose.
Pa.	Lycoming.	Jersey Mills.	Sandy loam.	Loose.
Pa.	Tioga.	Slate Run.	Loamy sand.	Loose.
Pa.	Tioga.	Slate Run.	Sandy loam.	Loose.
Pa.	Clearfield.	Clearfield.	Clay.	Binding.

SOIL (*continued*).					
Moisture.	Humus.	Rock.	Slope.	Aspect.	Quality.
Fresh.	Very Good.	Glacial drift.	Flat.	.....	II.
Fresh.	Very good.	Glacial drift.	Flat.	.....	II.
Fresh.	Very good.	Glacial drift.	Flat.	.....	II.
Moist.	Very good.	Alluvial.	Flat.	.....	II.
Dry.	Poor.	Glacial drift.	Flat.	.....	III.
Dry.	Poor.	Sandstone.	5°	E.	II.
Dry.	Burned.	Sandstone.	15°	S. E.	II.
Dry.	Burned.	Sandstone.	25°	S.	II.
Dry.	Burned.	Sandstone.	10°	W.	II.
Dry.	Burned.	Sandstone.	20°	S. W.	II.
Dry.	Burned.	Sandstone.	Undulating.	.....	II.
Dry.	Fair.	Sandstone.	25°	N.	III.
Dry.	Fair.	Sandstone.	30°	N.	III.
Fresh.	Burned.	Sandstone.	25°	E.	II.
Fresh.	Fair.	Sandstone.	20°	W.	II.
Fresh.	Good.	Sandstone.	10°	W.	I.
Dry.	Burned.	Sandstone.	25°	S. W.	III.
Fresh.	Good.	Sandstone.	20°	W.	I.
Fresh.	Burned.	Conglomerate.	25°	W.	II.

GROWING STOCK OF WHITE PINE.

Average height. Feet.	Diameter of average tree. Inches.	Age.	Number of trees.	Basal area. Sq. Ft.	Volume, including bark. Cu. Ft.	Volume, without bark. Cu. Ft.	Merchantable timber. Cu. Ft.	Merchantable timber. Board Feet.
51.6	7.3	50	197	56.82	1,619.0	1,397.0	555.8	1,170
50.5	7.1	48	331	91.10	2,478.0	2,195.0	745.6	1,574
53.0	7.9	51	250	84.97	2,444.0	2,194.0	734.0	2,008
62.1	10.0	60	175	94.77	3,308.0	2,878.9	1,756.2	4,215
45.0	7.8	68	219	71.33	1,961.0	1,706.0	1,058.0	1,080
70.8	12.4	102	72	60.05	2,173.0	1,934.0	1,576.0	4,560
75.0	11.4	103	147	103.13	4,161.0	3,702.0	3,110.5	7,920
90.0	16.1	128	85	120.26	5,441.1	4,902.0	4,377.3	19,000
93.3	19.8	131	44	93.78	4,331.0	3,855.0	3,546.0	15,590
80.0	19.4	135	41	84.25	3,420.4	3,044.0	2,778.0	12,724
97.7	24.1	138	23	63.54	3,036.0	2,702.0	2,422.0	14,040
92.0	17.9	229	61	106.89	5,017.0	4,465.0	4,068.0	17,500
84.0	16.6	231	41	61.73	2,817.0	2,507.0	2,269.0	9.127
115.2	23.8	233	37	114.40	5,966.0	5,400.0	4,940.0	24,483
113.3	26.9	237	39	114.95	5,766.0	5,093.0	4,735.0	24,597
127.6	24.9	245	44	146.44	8,912.0	7,932.0	7,377.0	41,708
90.0	21.8	240	25	64.52	2,880.7	2,564.0	2,359.0	12,125
130.0	28.3	245	18	78.59	4,612.4	4,065.0	3,796.7	23,246
117.5	24.7	259	37	122.63	6,762.6	5,993.8	5,598.8	32,156

SPECIES IN MIXTURE.			DENSITY.		
Most important species.	Number of trees.	Basal area. Sq. Ft.	White Pine.	Other species.	Holes and blanks
B., M., Sp., Fr., Hm.	165	45.35	0.35	0.3	0.35
B., M., Pop., Sp., Fr.	74	11.36	0.55	0.1	0.35
B., M., Cy., Bch., Sp., Fr.	139	42.2	0.65	0.3	0.05
B., Bch., Cy., M., A., Pop., Ced., Elm, NP.	74	27.81	0.6	0.15	0.25
O., B., NP.	9	2.64	0.55	0.05	0.4
O., Ch. Hm.	29	27.63	0.5	0.2	0.3
O., Ch., Hm., NP., A.	48	25.12	0.55	0.15	0.3
O., Ch.	5	3.1	0.6	.....	0.4
O., Ch., JP.	18	13.01	0.5	0.1	0.4
O., JP.	20	18.43	0.4	0.1	0.5
.....	.....	.....	0.4	.....	0.6
O., B., Ch., M., Hm,	110	107.59	0.5	0.5	.....
O., B., Ch., Hm., JP.	75	92.15	0.3	0.5	0.2
O., B., Ch., Hm., M.	17	14.45	0.45	0.05	0.5
O., Ch., M., Hm.	32	65.3	0.45	0.25	0.3
O., M., Ch., Hm.	36	84.7	0.5	0.3	0.2
O., Hm.	17	33.8	0.35	0.15	0.5
B., M., Hm.	81	101.68	0.3	0.4	0.3
Hm., O.	5	5.75	0.6	.....	0.4

The yield tables are based upon the valuation surveys given in the summary above. It would have been very difficult and equally undesirable to construct tables showing the actual yields measured per acre at the different ages, because the areas assessed were either not fully stocked by nature or had been thinned by fires or injudicious cutting, or else they contained a large percentage of other species in mixture. Consequently the results at different ages would have been more influenced by the degree of density than by any differences in the localities. The yield tables are therefore constructed to show, not the actual yield per acre as found in the valuation surveys, but the yield of acres fully stocked with pure White Pine. It is easy to reduce the figures to correspond with any less degree of density, simply by multiplying them by the decimal which expresses it. Thus the yield of an acre only half stocked with Pine would be found by multiplying the figure in the table by 0.5.

In the preparation of the tables the yields of the acres were divided by the respective density factors, and the yields for fully stocked acres were thus obtained. The latter were then plotted upon cross-section paper, on the horizontal lines or abscissæ of which the number of years

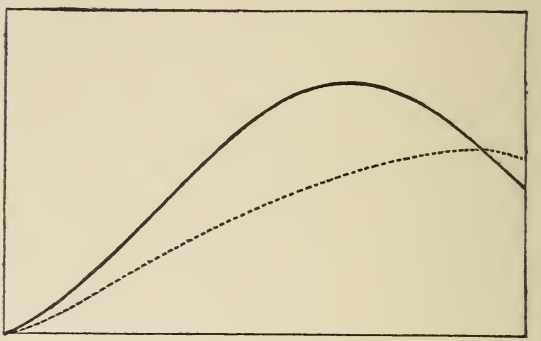
was laid off, and on the vertical lines or ordinates the number of cubic feet. Normal curves were then struck through the highest and lowest points. They represent the progress of the yield for the best and worst localities. An intermediate curve was also drawn for quality II.

The curves were drawn first for the yield per acre including the bark, and the values at the different ten-year periods were entered in yield tables, beginning with 30 years.

Curves for the yield per acre of Pine, excluding the bark, as well as curves for the yield of merchantable cubic and board feet, were also constructed.

The difference in the volumes for successive years in a given quality is the amount of wood laid on from year to year, or the current annual increment. The volume at a given period divided by the age is the mean annual increment. These values have been computed and are given in the yield tables. It will be seen that the mean annual increment culminates much later than the current annual increment, and further, that it culminates at a point where the two are equal. The current annual increment is at first very small, then rises rapidly to a much higher point than the mean annual increment ever reaches, and at last falls again.

FIG. 6.



——— Current annual increment.
----- Mean annual increment.

Since the mean annual increment at any time is the average of all the current annual increment of previous years, it is evident that when the latter falls below its own average, the average itself (or the mean annual increment) will have passed its highest point, which will necessarily be at the moment when both are equal. Thus for White Pine on land of first quality the mean annual increment, without bark, reaches its highest point in the table at 70 years, with a production of 98.6 cubic feet per acre. The current annual increment for the same age is 100 cubic feet per acre. At 80 years these values are 97.5 and 90 respectively. At some year between these two there is a point at which the mean annual increment rises from 98.6, and

the current annual increment falls from 100, to meet, at which the former culminates and the two are equal.

The mean annual as well as the current annual increment culminates earlier the better the quality of the locality. In quality I the current and mean annual increment of the wood and bark culminate respectively at 40 and 60 years. In quality II they culminate at 50 and 80, and in quality III not until 60 (or thereabouts) and 100.

The culmination of increment of the merchantable timber takes place later than that in which the entire stem is included. Thus in quality II the culmination for the current and mean annual increment occurs for the whole stem with the bark at 50 and 80 years respectively. For the merchantable timber expressed in cubic feet the corresponding points are at 60 and 100 years. To compute the growth in height of the various groups as simple a method as possible was employed. The growth in height of all the average trees of the valuation survey groups was plotted on cross-section paper and an average curve was thus obtained for each class. It may be said that the average tree at a given age has not always been the average tree, and that this method is consequently incorrect.

It is undoubtedly true that a tree which is the average tree at one period will not always be so; but by the use of the average trees of groups of different ages the error which may arise is almost wholly eliminated. The question is a very complicated one, and for the purpose in hand this method is sufficiently correct.

The height growth reaches its maximum rate earlier as the quality of the locality improves. The most rapid growth in height takes place between 15 and 20 years on soil of quality I, between 20 and 30 years on quality II, and between 30 and 40 years on quality III.

The diameter of the average tree was found by plotting the growths of the average trees of the various groups, and by constructing curves in the same way as for the height growth. (See Plate II.)

The basal areas of the valuation survey acres were computed for fully stocked acres and plotted on cross-section paper, and curves were constructed in the same manner as the curves for the volume yield. These curves were found to rise very rapidly at first, then to lay themselves over, and finally to run on a straight line.

The number of trees per acre is found from the material already obtained. The total basal area per acre at different periods is divided by

the basal area of the average stem for each period, and the result is the number of trees per acre.

It will be seen that the number of trees per acre increases as the locality grows poorer. This is easily explained by the smaller size of the individual trees.

Form factors were computed for the volume with bark to serve as a control for the tables. It will be seen that the form factors at first fall off and after a certain point rise again, and that they are larger the poorer the quality of the locality.

Yield Tables for fully stocked acres of White Pine in localities of quality I, II, and III, calculated for the whole contents of the stem, with and without bark, in cubic feet, and for the merchantable timber in cubic and board feet, together with form factors for the stem with the bark.

QUALITY I

Age.	Number of trees.	Basal Area breast-high.	Diameter of average tree.	Average height.	Stem with Bark.			
					Volume.	Current annual increment.	Mean annual increment.	Form factor
		Sq. ft.	Inches.	Feet.	Cu. ft.	Cu. ft.	Cu. ft.	
30	679	112.0	5.5	41.5	2,800	93.3	93.3	.602
40	485	145.0	7.4	54.5	4,250	145.0	106.3	.538
50	379	175.0	9.2	64.5	5,500	125.0	110.0	.487
60	309	200.0	10.9	72.5	6,750	125.0	112.5	.466
70	251	221.0	12.4	79.0	7,850	110.0	112.1	.450
80	228	237.0	13.8	84.25	8,850	100.0	110.6	.443
90	200	249.0	15.1	89.0	9,750	90.0	108.3	.440
100	178	258.5	16.3	93.25	10,550	80.0	105.5	.438
110	161	265.0	17.4	97.0	11,250	70.0	102.3	.438
120	146	269.0	18.35	100.5	11,900	65.0	99.1	.440
130	136	272.0	19.15	103.75	12,500	60.0	96.1	.443
140	126	273.0	19.95	107.0	13,025	52.5	93.0	.445
150	117	274.0	20.65	109.75	13,500	47.5	90.0	.449
160	111	274.0	21.3	112.5	13,925	42.5	87.0	.452
170	105	274.0	21.9	114.75	14,300	37.5	84.1	.455
180	100	274.0	22.4	117.0	14,650	35.0	81.4	.457
190	97	274.0	22.85	119.25	15,000	35.0	78.9	.459
200	93	274.0	23.3	121.5	15,300	30.0	76.5	.460
210	89	274.0	23.75	123.5	15,550	25.0	74.0	.460
220	86	274.0	24.15	125.0	15,750	20.0	71.6	.460
230	84	274.0	24.55	126.5	15,950	20.0	69.4	.460
240	81	274.0	24.9	128.0	16,150	20.0	67.3	.461
250	80	274.0	25.2	129.5	16,350	20.0	65.4	.461

QUALITY I

Stem without Bark.			Merchantable Timber Solid.			Merchantable Timber per Scale.			Age.
Volume Cu. ft.	Current annual increment. Cu. ft.	Mean annual increment. Cu. ft.	Volume Cu. ft.	Current annual increment. Cu. ft.	Mean annual increment. Cu. ft.	Am't. Board feet.	Current annual increment. B'd ft.	Mean annual increment. B'd ft.	
2,450	81.7	81.7	.....	.....	.....	.....	.....	.....	30
3,650	120.0	90.6	1,100	27.5	27.5	2,650	66.2	66.2	40
4,800	115.0	96.0	3,050	295.0	61.0	8,000	535	160.0	50
5,900	110.0	98.3	4,550	150.0	75.8	13,400	540	223.3	60
6,900	100.0	98.6	5,800	125.0	82.9	18,800	540	268.6	70
7,800	90.0	97.5	6,850	105.0	85.6	24,200	540	302.5	80
8,650	85.0	96.1	7,700	85.0	85.5	29,200	500	324.4	90
9,350	75.0	93.5	8,425	72.5	84.3	34,000	480	340.0	100
10,000	65.0	90.9	9,050	62.5	82.3	38,500	450	350.0	110
10,600	60.0	88.3	9,600	55.0	80.0	42,800	430	356.7	120
11,075	47.5	85.2	10,100	50.0	77.7	46,850	400	360.0	130
11,550	47.5	82.2	10,550	45.0	75.4	50,400	370	360.0	140
11,975	42.5	79.8	11,000	45.0	73.3	53,900	340	359.3	150
12,350	37.5	77.2	11,400	40.0	71.3	57,200	330	357.5	160
12,700	35.0	74.7	11,750	35.0	69.1	60,200	300	353.3	170
13,050	35.0	72.5	12,050	30.0	66.9	62,900	270	349.4	180
13,350	30.0	70.3	12,350	30.0	65.0	65,500	260	344.7	190
13,650	30.0	68.3	12,600	25.0	63.0	67,900	240	339.5	200
13,800	25.0	65.7	12,800	20.0	61.0	70,100	220	333.8	210
14,000	20.0	63.6	13,000	20.0	59.1	72,200	210	328.2	220
14,200	20.0	61.7	13,200	20.0	57.4	74,000	180	321.7	230
14,400	20.0	60.0	13,350	15.0	55.6	75,600	160	315.0	240
14,600	20.0	58.4	13,500	15.0	54.0	77,000	140	308.0	250

QUALITY II

Age.	Number of trees.	Basal Area breast-high.	Diameter of average tree.	Average height.	Stem with Bark.			
					Volume.	Current annual increment.	Mean annual increment.	Form factor.
		Sq. ft.	Inches.	Feet.	Cu. ft.	Cu. ft.	Cu. ft.	
30	1011	88.0	4.0	25.75	1,680	56.0	56.0	.741
40	661	113.0	5.6	36.5	2,500	82.0	61.7	.606
50	495	136.0	7.1	46.0	3,350	85.0	66.8	.535
60	396	156.0	8.5	55.75	4,150	80.0	69.1	.495
70	324	173.5	9.9	60.25	4,950	80.0	70.7	.474
80	280	188.0	11.1	65.5	5,700	75.0	71.3	.463
90	245	199.0	12.2	70.5	6,375	67.5	70.8	.454
100	217	208.0	13.25	74.5	7,000	62.5	70.0	.452
110	193	214.0	14.25	78.5	7,575	57.5	68.8	.451
120	174	218.0	15.15	82.0	8,150	57.5	67.9	.456
130	160	220.5	15.9	85.0	8,675	52.5	66.8	.463
140	148	221.5	16.6	88.0	9,150	47.5	65.4	.469
150	136	222.0	17.3	91.0	9,575	42.5	63.8	.474
160	127	222.0	17.9	93.5	9,950	37.5	62.2	.479
170	119	222.0	18.5	96.0	10,300	35.0	60.6	.483
180	113	222.0	19.0	98.0	10,575	27.5	58.8	.486
190	107	222.0	19.5	100.0	10,850	27.5	57.1	.489
200	102	222.0	20.0	102.0	11,100	25.0	55.5	.490
210	98	222.0	20.4	104.0	11,325	22.5	53.9	.490
220	94	222.0	20.8	105.5	11,525	20.0	52.4	.490
230	91	222.0	21.2	106.75	11,700	17.5	50.9	.490
240	88	222.0	21.5	108.0	11,850	15.0	49.4	.490
250	85	222.0	21.8	109.0	12,000	15.0	48.0	.491

QUALITY II

Stem without Bark.			Merchantable Timber Solid.			Merchantable Timber per Scale.			Age.
Volume Cu. ft.	Current annual increment. Cu. ft.	Mean annual increment. Cu. ft.	Volume Cu. ft.	Current annual increment. Cu. ft.	Mean annual increment. Cu. ft.	Am't. Board feet.	Current annual increment. B'd ft.	Mean annual increment. B'd ft.	
1,450	48.3	48.3	....	....	....	....	....	....	30
2,150	70.0	53.7	....	....	....	....	....	....	40
2,900	75.0	58.0	1,100	22.0	22.0	2,000	40.0	40.0	50
3,600	70.0	60.0	2,200	110.0	36.7	5,300	330.0	88.3	60
4,300	70.0	61.4	3,250	105.0	46.4	8,700	340.0	124.3	70
5,000	70.0	62.5	4,125	87.5	51.6	12,000	330.0	150.0	80
5,650	65.0	62.8	4,875	75.0	54.2	15,300	330.0	170.0	90
6,225	57.5	62.3	5,500	62.5	55.0	18,500	320.0	185.0	100
6,750	52.5	61.4	6,000	50.0	54.5	21,500	300.0	195.5	110
7,250	50.0	60.4	6,500	50.0	54.2	24,500	300.0	204.2	120
7,725	47.5	59.4	6,950	45.0	53.5	27,600	290.0	212.3	130
8,150	42.5	58.2	7,350	40.0	52.5	30,300	270.0	216.4	140
8,525	37.5	56.8	7,725	37.5	51.5	32,800	250.0	218.7	150
8,880	32.5	55.3	8,050	32.5	50.3	35,200	240.0	220.0	160
9,150	30.0	53.8	8,350	30.0	49.1	37,300	210.0	219.4	170
9,400	25.0	52.2	8,600	25.0	47.9	39,300	200.0	218.3	180
9,650	25.0	50.8	8,825	22.5	46.4	41,200	190.0	216.8	190
9,875	22.5	49.4	9,050	22.5	45.3	43,100	190.0	215.5	200
10,075	20.0	48.0	9,250	20.0	44.0	44,900	180.0	213.8	210
10,250	17.5	46.6	9,425	17.5	42.8	46,600	170.0	211.8	220
10,400	15.0	45.2	9,575	15.0	41.6	48,100	150.0	209.1	230
10,550	15.0	44.0	9,700	12.5	40.4	49,400	130.0	205.8	240
10,700	15.0	42.8	9,825	12.5	39.3	50,600	120.0	202.4	250

QUALITY III

Age.	Number of trees.	Basal Area breast-high.	Diameter of average tree.	Average height.	Stem with Bark.			
					Volume.	Current annual increment.	Mean annual increment.	Form factor.
		Sq. ft.	Inches.	Feet.	Cu. ft.	Cu. ft.	Cu. ft.	
30	1,478	68.0	2.9	15.0	850	28.3	28.3	.833
40	951	87.5	4.1	22.5	1,300	45.0	32.5	.660
50	686	105.0	5.3	30.0	1,800	50.0	36.0	.571
60	542	121.0	6.4	36.25	2,300	50.0	38.3	.524
70	435	133.5	7.5	42.0	2,800	50.0	40.0	.499
80	372	144.0	8.5	47.0	3,275	47.5	40.9	.484
90	310	152.5	9.5	51.5	3,725	45.0	41.4	.474
100	270	159.5	10.4	55.75	4,150	42.5	41.5	.466
110	241	164.5	11.2	59.5	4,550	40.0	41.4	.465
120	214	168.0	12.0	63.0	4,925	37.5	41.0	.465
130	193	170.0	12.7	66.25	5,275	35.5	40.6	.468
140	176	171.0	13.35	69.5	5,625	35.5	40.2	.473
150	161	172.0	14.0	72.0	5,950	32.5	39.6	.480
160	147	172.0	14.6	74.5	6,250	30.0	39.1	.488
170	137	172.0	15.15	77.0	6,500	25.0	38.2	.491
180	128	172.0	15.7	79.0	6,725	22.5	37.3	.495
190	120	172.0	16.2	81.0	6,950	22.5	36.6	.499
200	113	172.0	16.65	82.5	7,150	20.0	35.75	.504
210	108	172.0	17.05	84.0	7,325	17.5	34.9	.507
220	104	172.0	17.45	85.5	7,500	17.5	34.1	.510
230	99	172.0	17.85	86.75	7,650	15.0	33.3	.513
240	95	172.0	18.2	87.75	7,800	15.0	32.5	.518
250	92	172.0	18.5	88.5	7,925	12.5	31.7	.521

QUALITY III

Stem without Bark.			Merchantable Timber Solid.			Merchantable Timber per Scale.			Age.
Volume Cu. ft.	Current annual increment. Cu. ft.	Mean annual increment. Cu. ft.	Volume Cu. ft.	Current annual increment. Cu. ft.	Mean annual increment. Cu. ft.	Am't. Board Feet.	Current annual increment. B'd ft.	Mean annual increment. B'd ft.	
750	25.0	25.0	.....	.....	.....	.....	.....	.....	30
1,125	37.5	28.1	.....	.....	.....	.....	.....	.....	40
1,575	45.0	31.5	.....	.....	.....	.....	.....	.....	50
2,000	42.5	33.3	800	13.3	13.3	.....	.....	.....	60
2,425	42.5	34.6	1,500	70.0	21.4	1,900	27.1	27.1	70
2,850	42.5	35.6	2,150	65.0	26.9	3,700	180.0	46.3	80
3,275	42.5	36.6	2,700	55.0	30.0	5,500	180.0	61.7	90
3,700	42.5	37.0	3,150	45.0	31.5	7,300	180.0	73.0	100
4,050	35.0	36.8	3,500	35.0	31.8	9,100	180.0	82.7	110
4,375	32.5	36.5	3,800	30.0	31.7	10,900	180.0	90.8	120
4,700	32.5	35.2	4,100	30.0	31.5	12,700	180.0	97.7	130
5,000	30.0	35.7	4,400	30.0	31.4	14,500	180.0	103.5	140
5,300	30.0	35.3	4,700	30.0	31.3	16,200	170.0	108.0	150
5,550	25.0	34.7	4,950	25.0	30.9	17,900	170.0	111.9	160
5,800	25.0	34.1	5,175	22.5	30.4	19,500	160.0	114.7	170
6,000	20.0	33.3	5,375	20.0	29.9	21,000	150.0	116.7	180
6,200	20.0	32.6	5,575	20.0	29.3	22,400	140.0	117.9	190
6,375	17.5	31.9	5,750	17.5	28.7	23,700	130.0	118.5	200
6,525	17.5	31.1	5,900	15.0	28.1	24,900	120.0	118.6	210
6,675	15.0	30.3	6,050	15.0	27.5	26,000	110.0	118.2	220
6,800	12.5	29.6	6,200	15.0	27.0	27,000	100.0	117.4	230
6,925	12.5	28.9	6,300	10.0	26.3	28,000	100.0	116.5	240
7,050	12.5	28.2	6,400	10.0	25.6	28,900	90.0	115.6	250

VII

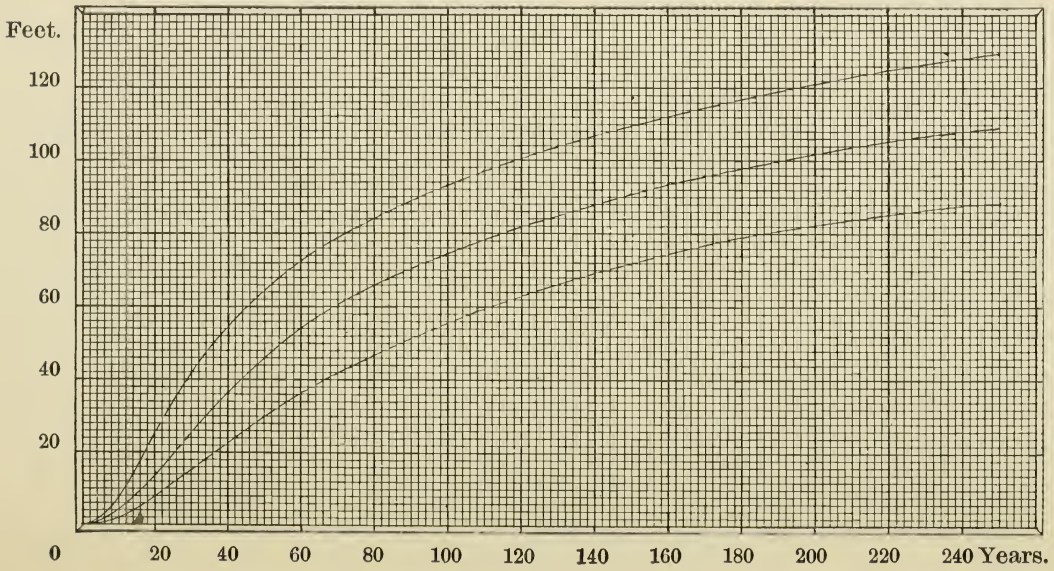
CURVES

THE calculations upon which these curves depend were made, where area is taken into account (Plates III–VI), on the basis of fully stocked acres, or acres of density 1. It will often be necessary, in using the curves, to make allowance for this fact. To do so the density of the group or forest must be estimated by reference to the cover, or forest canopy, as explained on page 61, and the figure given by the curve must then be reduced by multiplication with the decimal by which the density is expressed. A curve is drawn for each one of the three qualities of locality, as explained on page 72. According to the grade of the Pine with reference to which these curves are used, one or another of them must be employed. Correct results will depend very largely on the observance of this caution, and on a proper estimate of the density in each case.

CURVES FOR THE AVERAGE HEIGHT OF WHITE PINE GROUPS.

THIS Plate answers the question: How high is a White Pine forest at a given age? Thus it appears from the curves that in good soil the average height of a body of Pine timber 100 years old is 93 feet. In the preceding 50 years it grew from 64 feet to 93, an increase of 29 feet, while in the next 50 years it will grow but 17 feet, to reach, at the end of that time, the height of 110. It is easy to see from the shape of the curve that the period of most rapid growth was passed before the end of the first century.

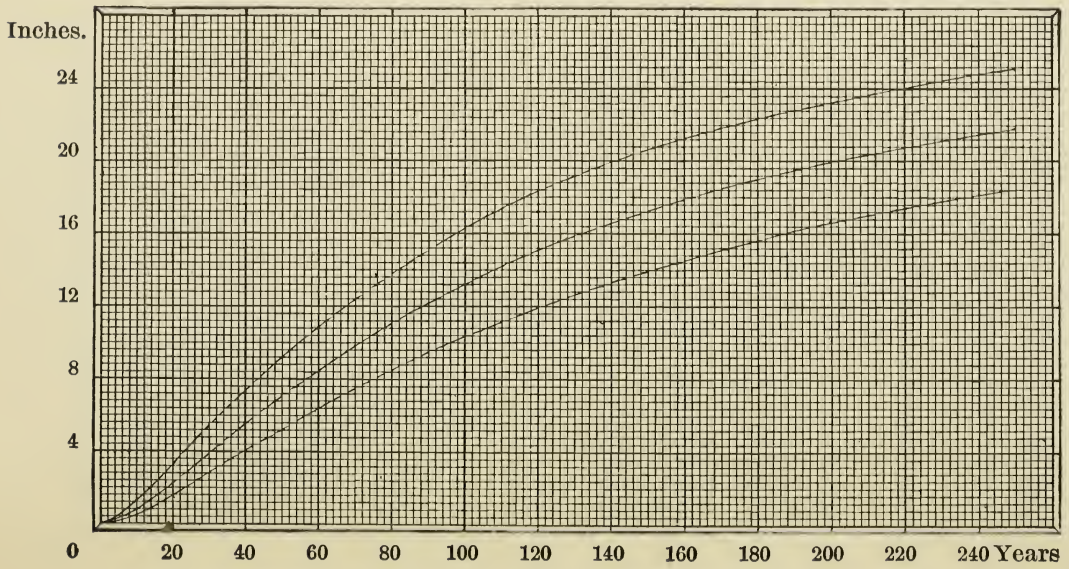
PLATE I.


Feet.
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
200
220
240 Years.

CURVES FOR THE DIAMETER OF THE AVERAGE TREE IN WHITE PINE GROUPS.

From this table it is possible to find the approximate probable age of a group of White Pine by means of callipers or a tape measure. Thus, if the diameter of an average tree of an even-aged group is found to be 16 inches, the probable age of the group will be 98 years in a locality of the first grade, 186 if the locality is poor, and 132 years if it is intermediate.

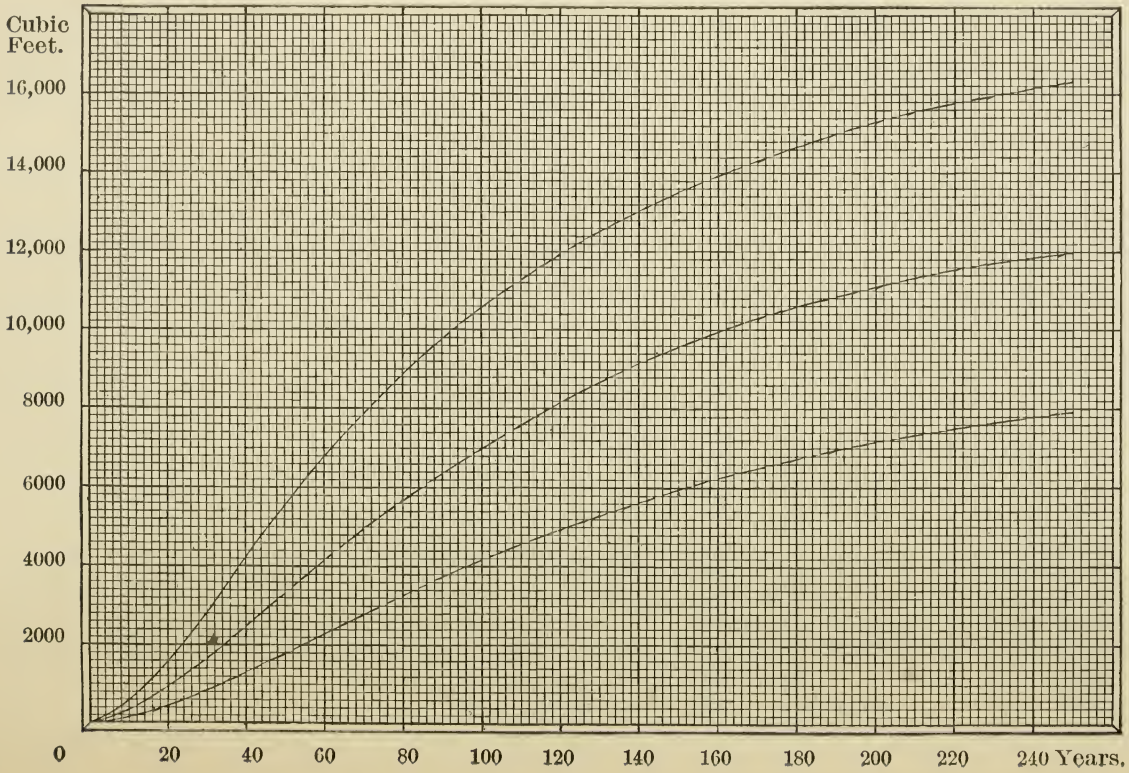
PLATE II.


Inches.
24
20
16
12
8
4
0
20
40
60
80
100
120
140
160
180
200
220
240 Years

CURVES FOR THE VOLUME OF WHITE PINE GROUPS, EXCLUDING BRANCHES.

If the present volume of a fully stocked acre of White Pine is known, this Plate makes it possible to find its approximate age, or vice versa. It can also be used to ascertain the density of an acre of known volume and age simply by dividing the quantity on the ground by the appropriate number found from the curve. By its means the growth of an acre of forest may be predicted, when its age and volume are known, for any desired time. By ascertaining the probable age from the diameter of the average tree through the use of Plate II, it is possible to discover the approximate age, volume per acre, and future increment of a forest of White Pine with no other instrument than a tape measure or a pair of callipers. If the estimate desired is a rough one, even these simple measurements may be dispensed with, and a result may be reached by the eye alone.

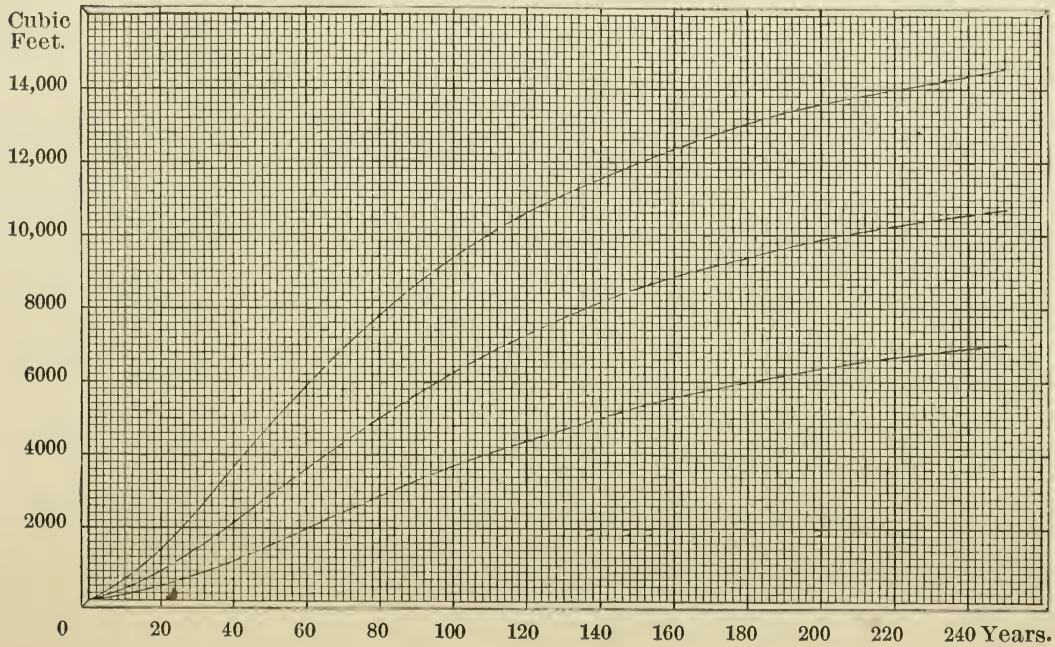
If an acre is only half stocked, the chances are that the future growth will be more than half that shown by the table, because the trees, as they grow and spread, will fill up the blanks. The density will increase with the age.


Cubic Feet.
16,000
14,000
12,000
10,000
8000
6000
4000
2000
0
20
40
60
80
100
120
140
160
180
200
220
240 Years.

CURVES FOR THE VOLUME OF WHITE PINE, EXCLUDING BARK AND BRANCHES.

THESE curves supply in general the same information as those of Plate III, except that they take account of nothing but the wood in the stem. They show, consequently, the total net product of the shafts in cubic feet of wood.

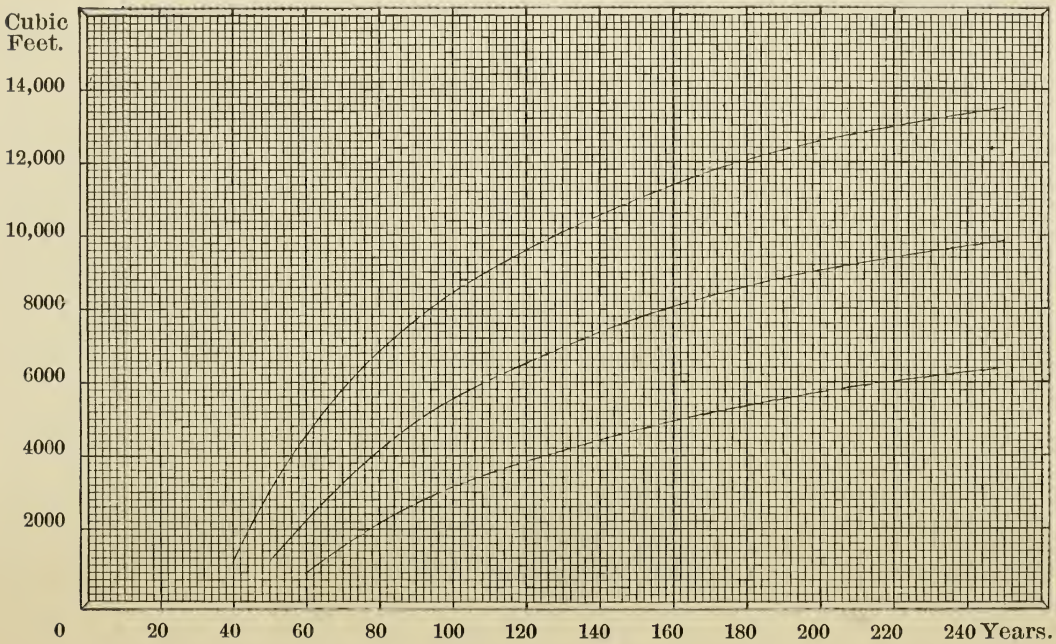
PLATE IV.


Cubic Feet.
14,000
12,000
10,000
8000
6000
4000
2000
0
20
40
60
80
100
120
140
160
180
200
220
240 Years.

CURVES FOR THE MERCHANTABLE YIELD OF WHITE PINE GROUPS, IN CUBIC FEET.

THIS Plate gives the total cubic contents of all the logs of merchantable size which could be cut from a fully stocked acre, at different ages and on different grades of locality, on the basis of the present practice of lumbermen. It should be remembered that the limit of size of merchantable logs is continually sinking. The most conspicuous fact which may be learned from this plate is that the yield begins at 40, 50, and 60 years respectively for the three grades of locality, although it is at first so small as to be of very moderate importance. But after the yield has once begun the rise is rapid and long sustained. Thus at 50 years a fully stocked acre of quality II will yield 1,100 cubic feet of merchantable timber. At 100 years it will yield 5,500 cubit feet, at 150 years 7,700, and at 250 years nearly 10,000 cubic feet.

PLATE V.


Cubic Feet.
14,000
12,000
10,000
8000
6000
4000
2000
0
20
40
60
80
100
120
140
160
180
200
220
240 Years.

97

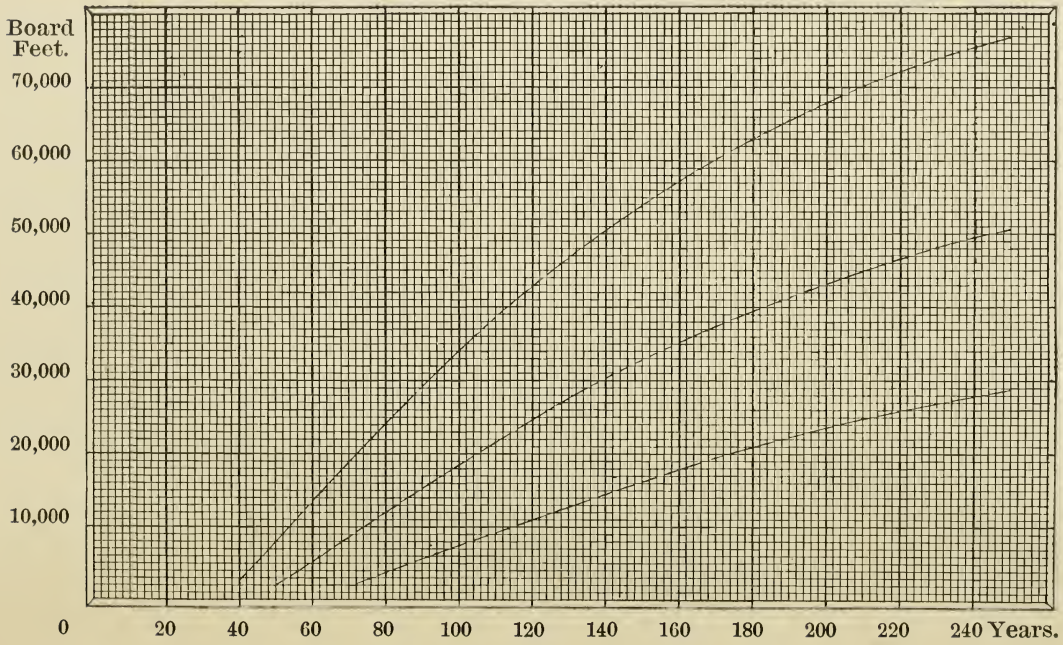
7

CURVES FOR THE YIELD OF WHITE PINE GROUPS IN BOARD FEET.

THESE curves are marked by a very late beginning and a very rapid, uniform, and long-sustained rise. On a locality of grade I, a White Pine acre which began with 2,500 feet at 40 years will reach 78,000 feet at the age of 250, and will still be growing at the rate of about 1,000 feet every six years.

If the age of a White Pine group is found by the curves in Plate II, its stand in board feet may be obtained from the present Plate, and its future increment in the same unit may then be seen at a glance. This Plate will also be found useful in arriving at the relation between the future value of Pine land and the expenses chargeable against it for protection, interest, and taxes. By balancing the probable rise in taxes against the probable rise in the value of stumpage, a very correct idea of the commercial wisdom of holding Pine lands for their future increment in lumber may be obtained. The result reached will be based on actual measurement and calculation, and will be correspondingly reliable.

PLATE VI.


Board Feet.
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
20
40
60
80
100
120
140
160
180
200
220
240 Years.

I

AREAS OF CIRCLES
FOR DIAMETERS OF 1 INCH TO 60 INCHES.[1]

Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.
1.0	.006	2.0	.022	3.0	.049	4.0	.087	5.0	.136	6.0	.196
.1	.007	.1	.024	.1	.052	.1	.092	.1	.142	.1	.203
.2	.008	.2	.026	.2	.056	.2	.096	.2	.147	.2	.210
.3	.009	.3	.029	.3	.059	.3	.101	.3	.153	.3	.216
.4	.011	.4	.031	.4	.063	.4	.106	.4	.159	.4	.223
.5	.012	.5	.034	.5	.067	.5	.111	.5	.165	.5	.230
.6	.014	.6	.037	.6	.071	.6	.115	.6	.171	.6	.238
.7	.016	.7	.040	.7	.075	.7	.121	.7	.177	.7	.245
.8	.018	.8	.043	.8	.079	.8	.126	.8	.184	.8	.252
.9	.020	.9	.046	.9	.083	.9	.131	.9	.190	.9	.260
7.0	.267	8.0	.349	9.0	.442	10.0	.545	11.0	.660	12.0	.785
.1	.275	.1	.358	.1	.452	.1	.556	.1	.672	.1	.799
.2	.283	.2	.367	.2	.462	.2	.568	.2	.684	.2	.812
.3	.291	.3	.376	.3	.472	.3	.579	.3	.697	.3	.825
.4	.299	.4	.385	.4	.482	.4	.590	.4	.709	.4	.839
.5	.307	.5	.394	.5	.492	.5	.601	.5	.721	.5	.852
.6	.315	.6	.403	.6	.503	.6	.613	.6	.734	.6	.866
.7	.323	.7	.413	.7	.513	.7	.625	.7	.747	.7	.880
.8	.332	.8	.422	.8	.524	.8	.636	.8	.760	.8	.894
.9	.340	.9	.432	.9	.535	.9	.648	.9	.772	.9	.908

[1] From Schlich's Manual of Forestry, Vol. III., by permission.

Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.
13.0	.922	14.0	1.069	15.0	1.227	16.0	1.396	17.0	1.576	18.0	1.767
.1	.936	.1	1.084	.1	1.244	.1	1.414	.1	1.595	.1	1.787
.2	.950	.2	1.100	.2	1.260	.2	1.431	.2	1.614	.2	1.807
.3	.965	.3	1.115	.3	1.277	.3	1.449	.3	1.632	.3	1.827
.4	.979	.4	1.131	.4	1.294	.4	1.467	.4	1.651	.4	1.847
.5	.994	.5	1.147	.5	1.310	.5	1.485	.5	1.670	.5	1.867
.6	1.009	.6	1.163	.6	1.327	.6	1.503	6	1.689	.6	1.887
.7	1.024	.7	1.179	.7	1.344	.7	1.521	.7	1.709	.7	1.907
.8	1.039	.8	1.195	.8	1.362	.8	1.539	.8	1.728	.8	1.928
.9	1.054	.9	1.211	.9	1.379	.9	1.558	.9	1.748	.9	1.948
19.0	1.969	20.0	2.182	21.0	2.405	22.0	2.640	23.0	2.885	24.0	3.142
.1	1.990	.1	2.204	.1	2.428	.1	2.664	.1	2.910	.1	3.168
.2	2.011	.2	2.226	.2	2.451	.2	2.688	.2	2.936	.2	3.194
.3	2.032	.3	2.248	.3	2.475	.3	2.712	.3	2.961	.3	3.221
.4	2.053	.4	2.270	.4	2.498	.4	2.737	.4	2.986	.4	3.247
.5	2.074	.5	2.292	.5	2.521	.5	2.761	.5	3.012	.5	3.275
.6	2.095	.6	2.315	.6	2.545	.6	2.786	.6	3.038	.6	3.301
.7	2.117	.7	2.337	.7	2.568	.7	2.810	.7	3.064	.7	3.328
.8	2.138	.8	2.360	.8	2.592	.8	2.835	.8	3.089	.8	3.355
.9	2.160	.9	2.383	.9	2.616	.9	2.860	.9	3.115	.9	3.382

Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.
25.0	3.409	26.0	3.687	27.0	3.976	28.0	4.276	29.0	4.487
.1	3.436	.1	3.715	.1	4.006	.1	4.307	.1	4.619
.2	3.464	.2	3.744	.2	4.035	.2	4.337	.2	4.650
.3	3.491	.3	3.773	.3	4.065	.3	4.368	.3	4.682
.4	3.519	.4	3.801	.4	4.095	.4	4.399	.4	4.714
.5	3.547	.5	3.830	.5	4.125	.5	4.430	.5	4.746
.6	3.574	.6	3.860	.6	4.155	.6	4.461	.6	4.779
.7	3.602	.7	3.888	.7	4.185	.7	4.493	.7	4.811
.8	3.631	.8	3.917	.8	4.215	.8	4.524	.8	4.844
.9	3.659	.9	3.947	.9	4.246	.9	4.555	.9	4.876
30.0	4.909	31.0	5.241	32.0	5.585	33.0	5.940	34.0	6.305
35.0	6.681	36.0	7.069	37.0	7.467	38.0	7.876	39.0	8.296
40.0	8.727	41.0	9.168	42.0	9.621	43.0	10.085	44.0	10.559
45.0	11.045	46.0	11.541	47.0	12.048	48.0	12.566	49.0	13.095
50.0	13.635	51.0	14.186	52.0	14.748	53.0	15.321	54.0	15.904
55.0	16.499	56.0	17.104	57.0	17.721	58.0	18.348	59.0	18.986
60.0	19.635								

Deacidified using the Bookkeeper process.
Neutralizing agent: Magnesium Oxide
Treatment Date: Nov. 2012

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